UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

APR 2001
RECE
WA
DIVISION

APR 27 2001

Mr. Larry Lawson
Virginia Department of Environmental Quality
629 Main Street
Richmond, VA 23219

Re: Mountain Run Fecal Coliform TMDL, Culpeper County

Dear Mr. Lawson:

The Environmental Protection Agency (EPA) Region III is pleased to approve the fecal coliform TMDL for Mountain Run. This TMDL was submitted for EPA review on March 30, 2001 in accordance with section 303 (d)(1)(c) and (2) of the Clean Water Act. This TMDL was established to address an impairment of water quality as identified in Virginia's 1998 Section 303 (d) list. Virginia identified the impairment for this water quality-limited segment within the Rappahanock watershed based on exceedances of the fecal coliform water quality standard.

In accordance with Federal Regulations in 40 CFR §130.7, a TMDL must be designed to meet water quality standards, and (1) include, as appropriate, wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources, (2) consider the impacts of background pollutant contributions, (3) take critical stream conditions into account (the conditions when water quality is most likely to be violated), (4) consider seasonal variations, (5) include a margin of safety (which accounts for uncertainties in the relationship between pollutant loads and instream water quality), and (6) be subject to public participation. The enclosure to this letter describes how the TMDL for Mountain Run satisfies each of these requirements.

According to 40 CFR 122.44 (d) (vii) (B) "Effluent limits developed to protect a narrative water quality criteria, numeric water quality criteria, or both, are consistent with the assumptions and requirements of any available wasteload allocation for the discharge prepared by the State and approved by EPA under 40 CFR 130.7." The TMDL currently has the urban runoff loading under the load allocation. Prior to the Town of Culpeper's MS-4 permit issuance, the TMDL must be modified to allow sufficient capacity under the total WLA for the new point source, i.e. the discharge covered by the MS-4 permit. EPA expects the State to submit the TMDL modifications to EPA for review and approval before the MS-4 permit is issued. If you have any further questions, please call me or have your staff contact Mr. Thomas Henry, the TMDL Program Manager at 215-814-5752.

Sincerely,

Jon M. Capacasa

~~Rebecca Hanmer,~~ Director
Water Protection Division
for

Enclosure

Decision Rationale
Total Maximum Daily Load of
Fecal Coliform for Mountain Run

I. Introduction

This document will set forth the Environmental Protection Agency's (EPA) rationale for approving the Total Maximum Daily Load (TMDL) of Fecal Coliform for Mountain Run submitted for final Agency review on March 30, 2001. Our rationale is based on the TMDL submittal document to determine if the TMDL meets the following 8 regulatory conditions pursuant to 40 CFR §130.

1. The TMDLs are designed to implement applicable water quality standards.
2. The TMDLs include a total allowable load as well as individual waste load allocations and load allocations.
3. The TMDLs consider the impacts of background pollutant contributions.
4. The TMDLs consider critical environmental conditions.
5. The TMDLs consider seasonal environmental variations.
6. The TMDLs include a margin of safety.
7. The TMDLs have been subject to public participation.
8. There is reasonable assurance that the TMDLs can be met.

II. Background

Located in Culpeper County, Virginia, the overall Mountain Run watershed is approximately 58,000 acres. The TMDL addresses 7.58 miles of Mountain Run from its confluence with Flat Run extending downstream to its confluence with the Rappahannock River. Agriculture is the predominant land use in the watershed. Mountain Run is a tributary to the Rappahannock River, which discharges to the Chesapeake Bay.

In response to Section 303 (d) of the Clean Water Act (CWA), the Virginia Department of Environmental Quality (VADEQ) listed 7.58 miles of Mountain Run as being impaired by elevated levels of fecal coliform on Virginia's 1998 Section 303 (d) list. Mountain Run was listed for violations of Virginia's fecal coliform bacteria standard for primary contact. Fecal coliform is a bacterium which can be found within the intestinal tract of all warm blooded animals. Therefore it can be found in the fecal wastes of warm blooded animals. Fecal coliform in itself is not a pathogenic organism. However, it indicates the presence of fecal wastes and the potential for the existence of other pathogenic bacteria. The higher concentrations of fecal coliform indicate the elevated likelihood of increased pathogenic organisms. Mountain Run, identified as watershed VAN-E09R, was given a high priority for TMDL development. Section 303 (d) of the Clean Water Act and its implementing regulations require a TMDL to be developed for those waterbodies identified as impaired by the State where technology-based and other controls do not provide for the attainment of Water Quality Standards. The TMDL submitted by Virginia is designed to determine the acceptable load of fecal coliform which can be delivered to Mountain Run, as demonstrated by the Hydrologic Simulation Program Fortran

(HSPF)[1], in order to ensure that the water quality standard is attained and maintained. These levels of fecal coliform will ensure that the Primary Contact usage is supported. HSPF is considered an appropriate model to analyze this watershed because of its dynamic ability to simulate both watershed loading and receiving water quality over a wide range of conditions.

The HSPF model is a comprehensive modeling system for simulation of watershed hydrology, point and nonpoint source loadings, and receiving water quality for conventional pollutants and toxicants[2]. More specifically HSPF uses precipitation data for continuous and storm event simulations to determine total fecal loading to Mountain Run from built-up areas, cropland, forest, pasture, loafing lots, and rural residential. The total land loading of fecal coliform is the result of the application of manure (livestock wastes), direct deposition from livestock and wildlife (geese, duck, racoon, muskrat, and deer) to the land, fecal coliform production from pets, and septic system failure.

The TMDL analysis allocates the application/deposition of fecal coliform to land based and instream sources. For land based sources the HSPF model accounts for the buildup and washoff of pollutants from these areas. Build up (accumulation) refers to all of the complex spectrum of dry-weather processes that deposit or remove pollutants between storms. Washoff is the removal of fecal coliform which occurs as a result of runoff associated with storm events. These two processes allow the HSPF model to determine the amount of fecal coliform reaching the stream from land based sources. Point sources and wastes deposited directly to the stream were treated as direct deposits. These wastes did not need a transport mechanism to allow them to reach the stream. The allocation plan calls for the reduction in fecal coliform wastes delivered by urban runoff, cattle in-stream, septic systems, and straight pipes.

Table #1 summarizes the specific elements of the TMDL.

Parameter	TMDL(cfu/yr)	WLA(cfu/yr)	LA(cfu/yr)	*MOS*[1] (cfu/yr)
Fecal Coliform	1.194×10^{15}	9.955×10^{12}	1.124×10^{15}	5.968×10^{13}

1 Virginia includes an explicit MOS by identifying the TMDL target as achieving the total fecal coliform water quality concentration of 190 cfu/100ml as opposed to the WQS of 200 cfu/ml. This can be viewed explicitly as a 5% MOS.

EPA believes it is important to recognize the conceptual difference between directly deposited loads (loads deposited to the stream) and land applied loads. Directly deposited loads represent the actual amount of fecal coliform being deposited into the stream segments. While values for flux sources (land applied sources) represent the amount of fecal coliform deposited to land. The actual amount of fecal coliform which reaches the stream will be less than the amount of fecal coliform deposited to land due to die-off, geography (distance to the stream), soil, and application method. The HSPF model, which considers landscape processes which affect the

[1]Bicknell, B.R., J.C. Imhoff, J.L. Little, and R.C. Johanson. 1993. Hydrologic Simulation Program-FORTRAN (HSPF): User's Manual for release 10.0. EPA 600/3-84-066. U.S. Environmental Protection Agency, Environmental Research Laboratory, Athens, GA.

[2]CH2MHILL, 2000. Fecal Coliform TMDL Development for Cedar, Hall, Byers, and Hutton Creeks Virginia.

total amount of fecal coliform runoff from land uses, determines the amount of fecal coliform which will reach the stream segment.

The United States Fish and Wildlife Service has been provided with a copy of this TMDL. A March 29, 2000 letter from the USFWS states "There are no known occurrences of federally listed species, nor is there designated critical habitat in the vicinity of the project."

III. Discussion of Regulatory Conditions

EPA finds that Virginia has provided sufficient information to meet all of the 8 basic requirements for establishing a fecal coliform TMDL for Mountain Run. EPA is therefore approving this TMDL. Our approval is outlined according to the regulatory requirements listed below.

1) The TMDL is designed to meet the applicable water quality standards.

Virginia has indicated that excessive levels of fecal coliform due to nonpoint sources (directly deposited into the River and urban runoff) have caused violations of the water quality standards and designated uses on Mountain Run. The water quality criterion for fecal coliform is a geometric mean 200 cfu (colony forming units)/100ml or an instantaneous concentration of no more than 1,000 cfu/100ml. Two or more samples over a thirty-day period are required for the geometric mean standard. Therefore, most violations of the State's water quality standard are due to violations of the instantaneous standard.

The HSPF model was used to determine the fecal coliform deposition rates to the land as well as loadings to the stream from point and direct deposition sources necessary to support the fecal coliform water quality criterion and primary contact use. The following discussion is intended to describe how controls on the loading of fecal coliform to Mountain Run will ensure that the criterion is attained.

Fecal coliform production rates within the watershed is attained from a wide array of sources on the farm practices in the area (land application rates of manure), the amount and concentration of farm animals, point sources in the watershed, animal access to the stream, wildlife in the watershed and their fecal production rates, land uses, urban runoff, weather, stream geometry, etc. This information is used in the development of the model.

The hydrology component of the model was developed using the flow data from USGS gage 01665000, which is located within the Mountain Run watershed. Data from this gage was available from January 1979 through September 1997. The hydrologic calibration was performed using data from 1986 through 1989. The model was then transferred to the downstream portion of Mountain Run. The calibration was performed using the USGS's HSPEXP program for analyzing calibration parameters. Thirty-two storms were selected from the 1/1/1986 to 12/31/1989 calibration period[3]. The percent error between observed and simulated flows were within the desired criterion of 10%. The withdrawal of water from the

[3]Yagow, G., 2001. Fecal Coliform TMDL Mountain Run Watershed Culpeper County, Virginia.

Culpeper Water Filtration Plant (WFP) and the discharge from the Culpeper Waste Water Treatment Plant (WWTP) had to be accounted for in the model as well. The WFP withdrew 1.39 million gallons a day (mgd) from Lake Pelham while the WWTP discharged 2.17 mgd to Mountain Run downstream of Culpeper. The water quality calibration used data from 1995 through 1997.

EPA believes that using HSPF to model and allocate fecal coliform will ensure that the designated uses and water quality standards will be attained and maintained for Mountain Run.

2) The TMDL includes a total allowable load as well as individual waste load allocations and load allocations.

Total Allowable Loads

Virginia indicates that the total allowable loading of fecal coliform is the sum of the loads allocated to land base, precipitation driven nonpoint source areas (cropland, pasture, loafing lots, rural residential, built-up areas, and forest) from flux sources, directly deposited nonpoint sources of fecal coliform (livestock in-stream, straight pipes, and lateral flow from septic systems), and point sources (Culpeper Waste Water Treatment Plant, Mt. Dumplin Sewage Treatment Plant (STP), Ferguson STP, and Mountain Run STP). Activities such as the application of manure, fertilizer, and the direct deposition of wastes from grazing animals are considered fluxes to the land use categories. The actual value for the total fecal load can be found in Table 1 of this document. The total allowable load is calculated on an annual basis due to the nature of HSPF model.

Waste Load Allocations

EPA regulations require that an approvable TMDL include individual Waste Load Allocations (WLAs) for each point source. According to 40 CFR 122.44(d)(1)(vii)(B), "Effluent limits developed to protect a narrative water quality criterion, a numeric water quality criterion, or both, are consistent with assumptions and requirements of any available WLA for the discharge prepared by the State and approved by EPA pursuant to 40 CFR 130.7." Furthermore, EPA has authority to object to the issuance of any NPDES permit that is inconsistent with the WLAs established for that point source.

There are several point sources on Mountain Run itself. However, the only regulated point source currently discharging is the Culpeper WWTP. There are three other facilities which although permitted to discharge fecal coliform are not currently discharging to Mountain Run. Under the future and all TMDL reduction scenarios, all of the facilities were modeled as discharging to the stream. The Waste Load Allocation for each facility was determined by multiplying the permitted fecal coliform concentration by the maximum flow. All of these facilities are required to treat their effluent for fecal coliform and therefore have concentrations far lower than their permitted limit. Table #2 documents the WLA for all of the permitted facilities discharging fecal coliform to Mountain Run. It should be noted that the Town of Culpeper's storm sewer system was modeled as a nonpoint source and is not yet permitted. In order to insure compliance with 40 CFR 122.44 (d) (vii) (B), the TMDL will need to be modified prior to the issuance of the Town of Culpeper's MS-4 permit to provide a WLA for that permitted discharge.

Table 2 - Summarizes the WLAs for each point source

Facility	Permit Number	Waste Load Allocation
Mt. Dumplin STP	VA0087149	8.29E+11
Ferguson STP	VA0062529	6.90E+09
Mountain Run STP	VA0090212	8.29E+11
Culpeper WWTP	VA0061590	8.29E+12
Total WLA	N/A	9.95E+12

Load Allocations

According to federal regulations at 40 CFR 130.2 (g), load allocations are best estimates of the loading, which may range form reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting loading. Wherever possible natural and nonpoint source loads should be distinguished.

In addition, VADEQ recognizes the significant loading of fecal coliform from cattle in-stream, straight pipes, and lateral flow from septic tanks within 500 feet of the stream. These sources are not dependent on a transport mechanism to reach a surface waterbody and therefore impact water quality during low and high flow events. These sources were modeled as though they were point sources.

Weather data is a critical component of the model. Wet weather events provide a transport mechanism (runoff) for land applied wastes to reach the stream. Therefore, it is vital that the weather data used accurately reflects the conditions in the watershed. A National Climatic Data Center cooperative observer station in Culpeper was used as the primary weather data source. Data from the Remington, Elkwood, and Piedmont Research Station was used to fill data gaps.

Urban runoff was the loading associated with runoff from impervious areas in the Town of Culpeper which bypass the WWTP and discharge directly to the stream. The runoff is from parking lots and other impervious structures which contain the fecal material from birds, pets, and rodents. A wet weather event is needed to transport this load to the stream. Fecal coliform was more easily transported from these impervious areas than from agricultural lands due to differing coefficients of runoff for these surfaces. Lower intensity storms were therefore, capable of transporting fecal material from built-up areas into the stream.

Subwatershed #9 of the TMDL model contains the majority of the Town of Culpeper, with all in-stream inputs of fecal coliform blocked by Lake Pelham[4]. Therefore monitored fecal coliform in this segment were attributed to urban sources. Monitoring data from 2000 has documented fecal coliform concentrations at the analysis threshold 8,000 cfu/100ml within this reach.

Urban runoff was modeled as a nonpoint source in the model and its loading was incorporated into the LA. The Town of Culpeper will be receiving an MS-4 permit in the future, in order for this permit to be approvable, it must be consistent with the WLA. Therefore, the storm sewer loading must be moved from the LA to the WLA prior to the issuance of the permit. Table #3 documents the loading to Mountain Run from each land use. The TMDL called for reductions in nonpoint source loading from cattle in-stream, urban runoff, straight pipes, and septic systems. Table #3A documents the reductions needed in each watershed for straight pipes, cattle in-stream, septic systems, and urban runoff.

Table #3 - Documents the edge of stream loads under current conditions and TMDL allocation plan #4 (cfu/yr x 10,000,000,000).

Source	Current Load	Allocated Load
Urban	2,241	2,534
Rural Residential	114	34
Forest	880	833
Cropland	1,228	1,218
Pasture	70,162	69,374
Loafing Lot	8,421	8,419
Impervious Washoff	22,323	5,938
Cattle In-stream	6,663	342
Straight Pipes	2,009	0

[4]Yagow, G., 2001. Fecal Coliform TMDL for Mountain Run Watershed Culpeper County, Virginia.

Table #3A - Load reductions in each watershed.

Source	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Urban Washoff				95				95	96	95	95	95		95		
Cattle in-stream		95	90	90	95	95	95			95	100	95		90		
Septic systems	100	100	100	100	100	100	100			100	100	100		100		
Straight Pipes		100	100	100	100	100	100	100	100	100	100	100	100	100		

3) The TMDL considers the impacts of background pollution.

The Mountain Run TMDL considered background as being the load delivered by wildlife. In this TMDL, wildlife was not modeled as delivering a fecal coliform load directly to the stream. Wildlife habitats were documented within the watershed. The fecal coliform loading was determined by estimating the wildlife population in the habitat and multiplying the population by the fecal coliform produced per animal. Lake Pelham was treated as a sink which prevented the migration of the upstream fecal coliform load to the downstream portion of the watershed.

4) The TMDL considers critical environmental conditions.

EPA regulations at 40 CFR 130.7 (c)(1) require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of Mountain Run is protected during times when it is most vulnerable.

Critical conditions are important because they describe the factors that combine to cause a violation of water quality standards and will help in identifying the actions that may have to be undertaken to meet water quality standards[5]. Critical conditions are a combination of environmental factors (e.g., flow, temperature, etc.), which have an acceptably low frequency of occurrence but when modeled to, insure that water quality standards will be met for the remainder of conditions. In specifying critical conditions in the waterbody, an attempt is made to use a reasonable "worst-case" scenario condition. For example, stream analysis often uses a low-flow (7Q10) design condition because the ability of the waterbody to assimilate pollutants without exhibiting adverse impacts is at a minimum.

The sources of bacteria for these stream segments were mixtures of dry and wet weather driven sources. The reductions called for in this TMDL will reduce the fecal coliform loading to the stream in both wet and dry weather conditions.

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[5]EPA memorandum regarding EPA Actions to Support High Quality TMDLs from Robert H. Wayland III, Director, Office of Wetlands, Oceans, and Watersheds to the Regional Management Division Directors, August 9, 1999.

5) The TMDLs consider seasonal environmental variations.

Seasonal variations involve changes in stream flow as a result of hydrologic and climatological patterns. In the continental United States, seasonally high flow normally occurs during the early spring from snow melt and spring rain, while seasonally low flows typically occur during the warmer summer and early fall drought periods. Consistent with our discussion regarding critical conditions, the HSPF model and TMDL analysis will effectively consider seasonal environmental variations.

The model also accounted for seasonal variations in fecal coliform loading. Fecal coliform loads changed for many of the sources depending on the time of the year. For example, cattle spent more time in the stream in the summer and animals were confined for longer periods of time in the winter. Therefore, the loading from cattle in-stream was greatest in the summer when there were more cattle in the stream for longer periods of time. This loading was further enhanced by the low flows encountered during the summer months.

6) The TMDLs include a margin of safety.

This requirement is intended to add a level of safety to the modeling process to account for any uncertainty. Margins of safety may be implicit, built into the modeling process by using conservative modeling assumptions, or explicit, taken as a percentage of the wasteload allocation, load allocation, or TMDL.

Virginia used an explicit margin of safety by establishing the TMDL target water quality concentration for fecal coliform at 190 cfu/ 100mL, which is more stringent than Virginia's water quality standard of 200 cfu/100 mL.

7) The TMDLs have been subject to public participation.

This TMDL was subject to a number of public meetings. Three public meetings were held in Culpeper, VA. The meeting were held on June 2, 1999, September 27, 1999, and May 10, 2000 and were intended to address initial questions and concerns regarding outreach issues and the TMDL process.

The first public meeting was held on June 2, 1999 in Culpeper and was announced in the Virginia Register on May 24, 1999 initiating the public comment period. The public comment period ended on June 23, 1999. The second public meeting was announced in the Virginia Register on September 13, 1999. The second public comment period closed 30-days after the announcement in the Virginia Register (October 12, 1999). The May 10, 2000, public meeting was announced in the April 24, 2000 Virginia Register and the public comment period closed on September 30, 2000. Several written comments were sent to the Commonwealth on this TMDL. The Commonwealth responded to these comments and submitted these responses to EPA.

8) There is a reasonable assurance that the TMDL can be met.

EPA requires that there be a reasonable assurance that the TMDL can be implemented. WLAs will be implemented through the NPDES permit process. According to 40 CFR 122.44(d)(1)(vii)(B), the effluent limitations for an NPDES permit must be consistent with the assumptions and requirements of any available WLA for the discharge prepared by the state and approved by EPA. Furthermore, EPA has authority to object to issuance of an NPDES permit that is inconsistent with WLAs established for that point source.

Nonpoint source controls to achieve LAs can be implemented through a number of existing programs such as Section 319 of the Clean Water Act, commonly referred to as the Nonpoint Source Program. Additionally, Virginia's Unified Watershed Assessment, an element of the Clean Water Action Plan, could provide assistance in implementing this TMDL.

Fecal Coliform TMDL
Mountain Run Watershed
Culpeper County, Virginia

Submitted by

Virginia Department of Environmental Quality

Virginia Department of Conservation and Recreation

Prepared by

Gene Yagow

Department of Biological Systems Engineering

Virginia Tech

March 2001

Revised April 2001

For additional information, please contact:

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Members of the Mountain Run Watershed Citizens Advisory Committee
Members of the Mountain Run Watershed Technical Advisory Committee
Culpeper Soil and Water Conservation District – Greg Wilchens, Debbie Fisher, Jim Byrne, Frances Smith, Paul Muhlberger
Culpeper Co. Planning Department – Pamela Schiermeyer
Culpeper Co. Public Works Department – Jim Hust, Randy Lindsey, Clarke Wallcraft
DCR - Patricia Miller, Jamie Lowry, Debbie Cross, Mary Apostolico, Robert Shoemaker, Tony Pane
Rappahannock-Rapidan Planning District Commission – Gary Christie, Amy Garber, Rick Stroemple
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Virginia Tech Biology Department – George Simmons, Sue Herbein

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Introduction

The Mountain Run watershed (state hydrologic unit E09) is located across the central portion of Culpeper County, Virginia and includes most of the Town of Culpeper. Mountain Run flows in an easterly direction into the Rappahannock River and eventually discharges into the Chesapeake Bay. The Mountain Run watershed is located within the Rappahannock River (USGS hydrologic unit 02080103) and eventually flows into the Chesapeake Bay. Mountain Run watershed contains approximately 58,000 acres.

Water quality samples collected from Mountain Run between July 1992 and June 1997 had fecal coliform concentrations that violated Virginia's instantaneous water quality standard in 25% of the samples. Based on these violations, the Virginia Department of Environmental Quality (DEQ) has classified Mountain Run as being impaired due to fecal coliform bacteria. The impaired segment is 7.58 miles in length, beginning at the confluence of Mountain Run with the Rappahannock River extending upstream to Mountain Run's confluence with Flat Run. An analysis of the water quality measurements in the watershed showed that violations of the fecal coliform standard occurred during both ambient and runoff conditions, with a high probability of violation during high flow. A wide range of fecal coliform concentrations was measured over a short period of time. Repeated high fecal coliform concentrations were measured in one sub-area of the watershed, but their impact on downstream ambient concentrations was unclear.

Fecal Coliform Sources

Fecal coliform in the watershed originate from nonpoint and direct nonpoint sources from livestock, wildlife and humans. There are four permitted sources of fecal coliform in the watershed, but no fecal coliform are currently detected in their effluent. Livestock contributions from beef, dairy, swine and horses were categorized as coming from four types of areas: pastures, cropland spreading areas, loafing lots, and stream access areas ("cows-in-streams"). The major types of wildlife considered were deer, raccoon, muskrat, geese, and ducks. Fecal coliform on urban impervious areas was simulated as a calibrated, lumped daily buildup rate from unspecified sources. Human contributions were identified as septic system failures and homes without facilities for treating their waste discharge ("straight pipes").

"Cows-in-streams" and "straight pipes" are considered to be direct nonpoint sources, as their contributions are direct to the stream, even though their sources are widely distributed throughout the watershed. Fecal coliform loads were estimated on a monthly basis to account for seasonal variability in production and practices, considering factors such as the fraction of time cattle are in confinement, time spent in streams, and manure storage and spreading schedules.

Modeling

The Hydrologic Simulation Program-Fortran (HSPF), version 11, was used to simulate the fate and transport of fecal coliform in the Mountain Run watershed, considering its various land uses, hydrologic attributes. The hydrology component of the model was calibrated on a smaller upstream portion of the watershed where a USGS flow gage (USGS Station No. 01665000) was operated through September 1997. The calibration was performed on a four-year period from January 1986 through December 1989, and validation using a separate four-year period from January 1982 through December 1985.

A large impoundment – Lake Pelham, downstream from the calibration site, was assumed to block fecal coliform transport downstream. Therefore, the model was simplified by disregarding all upstream sources of fecal coliform and simulating hydrologic inputs as the actual flow recorded at the upstream USGS flow gage. This simplification of upstream inputs allowed for a wider distribution of downstream spatial inputs, given the constraining limits of the model. Sub-watershed 9 – comprised primarily of urban and urban-related land uses – was used to calibrate urban buildup and washoff rates with observed and literature values of in-stream fecal coliform concentrations, while calibration of fecal coliform concentrations from all sources was performed at the watershed outlet. The fecal coliform calibration at both sites was limited to the January 1996 through September 1997 period, to correspond with available observed data.

Existing Conditions

Monthly fecal coliform loadings to different land-use categories were calculated for each sub-watershed for input into the model. Suspected "straight pipes" and "cows-in-streams" were modeled as direct nonpoint sources as direct inputs to the streams. Daily water withdrawals and additions were accounted for from the Town of Culpeper's Water Filtration and Wastewater Treatment (WWTP) plants. No fecal coliform have been detected recently in the WWTP effluent, so concentrations were modeled as zero for existing conditions.

Results from initial runs of the model configured for "existing conditions" showed that the state's 30-day geometric mean fecal coliform standard of 200 cfu/100 mL would be exceeded 59% of the time during the 4-year simulation period. The major fecal loads were identified as livestock on the land and washoff from impervious areas. Since the fecal coliform standard is written as a concentration, loading must be considered over time and in relationship with flow, in order to identify events and conditions producing the violations. Loading from land-applied fecal sources had little impact on the 30-day geometric mean concentration. The major influences on the 30-day geometric mean concentrations were not the same as those producing the highest loads. Of the two major influences on the 30-day geometric mean, one was a direct nonpoint source – "cows-in-streams" – which dominated during lower flow conditions, and the other was washoff from impervious areas, which dominated during higher flow conditions.

Margin of Safety (MOS)

To account for uncertainties in the modeling, a margin of safety was included by developing the TMDL allocations based on a target that was 5% lower than the standard. The TMDL was developed to account for future population growth and accompanying land use changes. Because of the MOS, the maximum 30-day geometric mean target for the allocation scenario was 190 cfu/100 mL, 5% below the standard (200 cfu/100 mL).

TMDL Allocation Scenarios

The Mountain Run TMDL was developed to account for future population growth and accompanying land use changes. The Mountain Run TMDL reserves fecal coliform loads for each permitted point source as their maximum monthly-averaged daily flow times the state 30-day geometric mean standard of 200 cfu/100 mL. After calibrating to the existing water quality conditions, different scenarios were evaluated to identify implementable scenarios that meet the target TMDL with zero violations, as shown in the Table 1 below. Since septic system failures and "straight pipes" are in violation of existing regulations, 100% reductions from these sources is a basic component of all Mountain Run TMDL alternatives. All TMDL allocation scenarios are based on reductions from the two major sources influencing in-stream concentrations – "cows-in-streams", and runoff from urban impervious areas.

Table 1. TMDL Alternative Scenario Reductions By Sub-Watershed

TMDL Scenario	Reach	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
TMDL Alt 1	urb washoff				84	84	84	84	84	84	84	84	84		84		
	cows-in-stream		100	100	100	100	100	100			100	100	100		100		
	septic systems	100	100	100	100	100	100	100			100	100	100		100		
	straight pipes		100	100	100	100	100	100	100	100	100	100	100	100	100		
TMDL Alt 2	urb washoff				100	100	100	100	100	100	100	100	100		100		
	cows-in-stream		82	82	82	82	82	82			83	82	82		82		
	septic systems	100	100	100	100	100	100	100			100	100	100		100		
	straight pipes		100	100	100	100	100	100	100	100	100	100	100	100	100		
TMDL Alt 3	urb washoff				92	92	92	92	93	93	93	92	92		93		
	cows-in-stream		92	92	93	93	93	92			93	92	92		92		
	septic systems	100	100	100	100	100	100	100			100	100	100		100		
	straight pipes		100	100	100	100	100	100	100	100	100	100	100	100	100		
TMDL Alt 4	**urb washoff**				**95**				**95**	**96**	**95**	**95**	**95**		**95**		
	cows-in-stream		**95**	**90**	**90**	**95**	**95**	**95**			**95**	**95**	**95**		**90**		
	septic systems	**100**	**100**	**100**	**100**	**100**	**100**	**100**			**100**	**100**	**100**		**100**		
	straight pipes		**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**		
TMDL Alt 5	urb washoff				90	90	90		90	90	70	90			90		
	cows-in-stream		95	95	95	95	95	95			95	95	95		95		
	septic systems	100	100	100	100	100	100	100			100	100	100		100		
	straight pipes		100	100	100	100	100	100	100	100	100	100	100	100	100		

The recommended TMDL alternative – TMDL Alt 4 – will require reductions by sub-watershed, in the range of 90-95% from "cows-in-streams" and 0-96% from urban impervious area washoff. The scenarios above assume full implementation of the Mountain Run TMDL.

For the selected scenario (TMDL Alt 4), load allocations were calculated using the following equation:

$$\text{TMDL} = \sum \text{WLA} + \sum \text{LA} + \text{MOS}$$

where,

WLA = wasteload allocation (point source contributions);

LA = load allocation (nonpoint source contributions); and

MOS = margin of safety, 5% of TMDL.

Based on reductions required from projected future conditions and fecal coliform loadings, the summary of the Mountain Run fecal coliform TMDL is given in Table 2.

Table 2. The Mountain Run Fecal Coliform TMDL Summary

å **WLA**	å **LA**	**MOS**	**TMDL**
9.95 x 10^{12} cfu/yr	871.00 x 10^{12} cfu/yr	46.37 x 10^{12} cfu/yr	927.32 x 10^{12} cfu/yr

Implementation

Although current Federal regulations do not specify implementation mechanisms, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act directs DEQ to develop plans for expeditious implementation of TMDLs, and constitutes a reasonable assurance that implementation will occur in Mountain Run. Implementation of best management practices (BMPs) in Mountain Run will occur in stages. A potential Stage I implementation goal for Mountain Run is to reduce violations of the state's instantaneous fecal coliform standard – 1,000 cfu/100 mL – to 10% or less. The stage I allocation scenario to meet this endpoint requires reductions from "cows-in-streams" of 60% and from urban impervious runoff of 50%.

Reasonable Assurance

A transitional TMDL implementation plan has been developed that allows for the interim evaluation of the effectiveness of the proposed TMDL implementation while progressing toward compliance with Virginia's water quality standard. Stage 1 implementation allows for the evaluation of installed management practice effectiveness through monthly stream monitoring. Also, data collection during this stage allows for the quantification of uncertainties that affect TMDL development. By accounting for such uncertainties, the TMDL can be improved for the final implementation stage that requires full compliance with the 200 cfu/100 mL geometric mean water quality standard.

Public Participation

Public participation was invited at every stage of TMDL development in order to receive input from stakeholders and to inform stakeholders of progress made. A Project Team consisting of local conservation agency personnel was consulted frequently and assisted in data gathering. The Mountain Run Watershed Citizens Advisory Committee and the Mountain Run Watershed Technical Advisory Committee were formed in 1996 as part of a §319 project to initiate TMDL development in Mountain Run, and were convened periodically by the Rappahannock-Rapidan Planning District Commission for updates on TMDL development progress in the Mountain Run watershed. Finally, in compliance with the

EPA requirement for public participation, three public meetings were organized and conducted by the state as part of the formalized TMDL process. The meetings on June 2, 1999 and September 27, 1999 discussed various aspects of TMDL development, while the third meeting on May 10, 2000 presented the draft TMDL plan.

1.0 INTRODUCTION

{tc \l1 "1.0 INTRODUCTION}

1.1 Background

{tc \l2 "1.1 Background}

Section 303(d) of the Federal Clean Water Act and the U.S. Environmental Protection Agency's (USEPA) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to identify waterbodies that violate state water quality standards and to develop Total Daily Maximum Loads (TMDLs) for such waterbodies. A TMDL is defined as follows for any given point in time:

$$TMDL = WLA + LA + MOS$$

where TMDL = the target load or concentration,
WLA = the point source load or concentration,
LA = the non-point source load or concentration, and
MOS = margin of safety.

TMDLs developed to meet a concentration standard are dependent on time-variable flow conditions. A TMDL, therefore, can either be the maximum allowable pollutant load received by, or the maximum concentration of a pollutant measured in, a water body, such that it does not exceed the governing water quality standard or criteria. A TMDL plan quantifies the various sources of the target pollutant, determines the load reductions by source needed to attain the target TMDL load or concentration, and provides a framework for taking actions to restore water quality.

Fecal coliform bacteria are found in the intestinal tract of warm-blooded animals; consequently, fecal waste of warm-blooded animals contains fecal coliform. Even though fecal coliform is not pathogenic, its presence in water indicates the potential for contamination by fecal material. Since fecal material can contain other pathogenic organisms, waterbodies with high fecal coliform counts are likely to contain higher concentrations of pathogenic organisms. For recreational activities where the potential for contact with water is high, such as, boating and swimming, health risks increase with increasing fecal coliform count in the waterbody. If the fecal coliform concentration in a waterbody exceeds state water quality standards, the waterbody is listed for violation of the state fecal coliform standard for contact recreational uses. The Virginia Department of Environmental Quality (DEQ) has identified Mountain Run as being impacted by fecal coliform bacteria for a length of 7.58 miles, as reported in both the 1996 and 1998

303(d) TMDL priority lists of water quality limited waters in Virginia (DEQ; 1996, 1998).

The Mountain Run watershed is located across the middle of Culpeper County, Virginia as shown in Figure 1-1, approximately 40 miles north of Charlottesville, Virginia and 70 miles southwest of Washington, D.C. Mountain Run flows in an easterly direction into the Rappahannock River and eventually discharges into the Chesapeake Bay. The Mountain Run watershed is located within the Rappahannock River hydrologic unit (02080103), and comprises the state hydrologic unit E09. Mountain Run watershed contains approximately 58,000 acres. It includes the Town of Culpeper, 5 water supply and flood detention reservoirs, and is approximately 25% forested, 60% agricultural and 15% urban and rural residential. The western portion of the watershed contains the urban area and reservoirs, while the eastern half is a mixture of forest and agriculture with scattered rural residences.

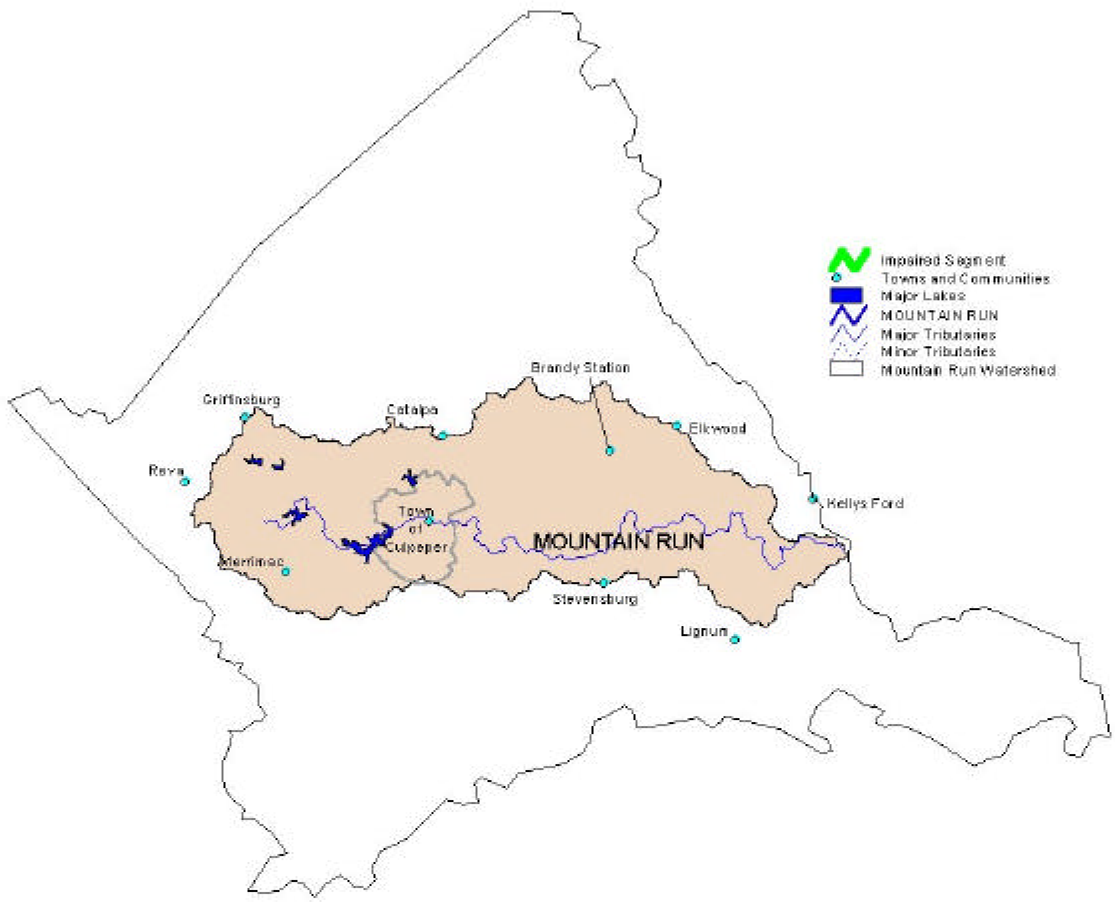

Figure 1-1. Location of Mountain Run in Culpeper County, Virginia

The impaired segment begins at the confluence of Mountain Run with the Rappahannock River and extends upstream to its confluence with Flat Run as shown in Figure 1-2. Mountain Run was given a high priority ranking on the 1998 list for TMDL development and has the DEQ waterbody code VAN-E09R. Waters ranked high priority are targeted for TMDL development during the current 1999-2000 biennium.

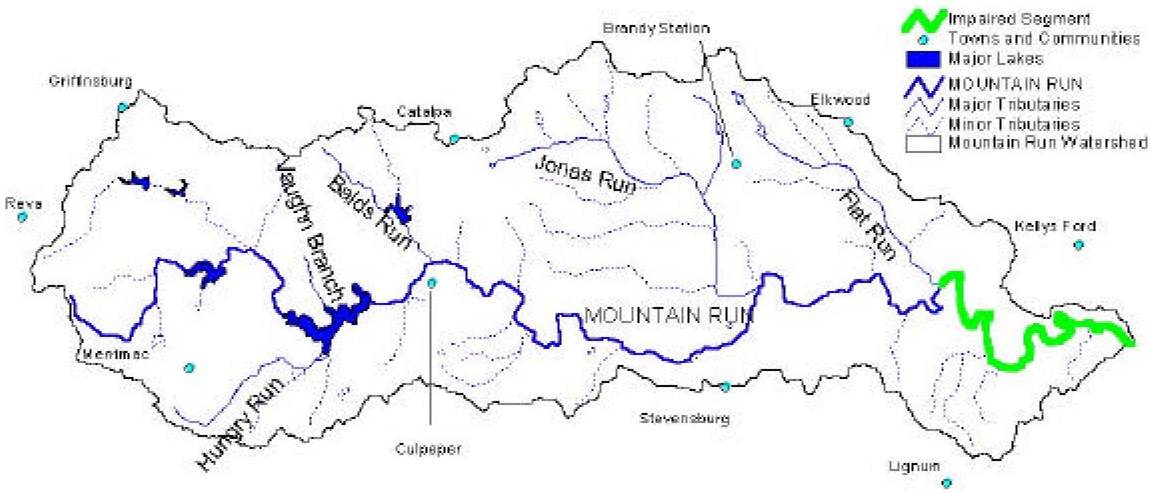

Figure 1-2. The Impaired Stream Segment in Mountain Run

1.2 Applicable Water Quality Standards

{tc \l2 "1.2 Applicable Water Quality Standards**}**

All waters of Virginia, including Mountain Run, are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish) (9VAC 25-260-10). Mountain Run was listed on the Virginia Department of Environmental Quality (DEQ) 1996 and 1998 303(d) TMDL priority lists as being impaired by fecal coliform bacteria. Sufficient fecal coliform bacteria standard violations were recorded at the DEQ water quality monitoring station at the Route 620 Bridge to indicate that the recreational use designations are not being supported (DEQ, 1998).

Virginia has a two-part water quality standard for fecal coliform bacteria in non-shellfish waters never to be exceeded: an instantaneous limit of 1,000 counts[1]/100 mL sample, and a geometric mean of 200 counts/100 mL for two or more samples taken over a 30-day period. Most of DEQ's ambient water quality monitoring is done on a monthly or quarterly basis, which does not provide the two or more samples within 30 days needed for comparison with the geometric mean part of the standard. Therefore, DEQ compares individual sample counts with 1,000 cfu/100 mL, the instantaneous part of the standard, to determine whether or not an individual sample violates or complies with the state water quality standard. Repeated violations, in excess of 25% of samples taken during each 5-year assessment period, result in waters being declared as “impaired” and listed on Virginia’s 303(d) TMDL priority list. The model simulations, performed in conjunction with this TMDL, simulate flow and concentration on a continuous basis, so that simulated output may be compared with the 30-day geometric mean standard of 200 cfu/100 mL.

1.3 The TMDL Targeted Endpoint

{tc \l2 "1.2 Applicable Water Quality Standards**}**

One of the major components of a TMDL is the establishment of an in-stream numeric endpoint. The in-stream numeric endpoint represents the water quality goal that is to be achieved by implementing the load reductions specified in the TMDL. The endpoint allows for a comparison between observed in-stream pollutant levels and predicted pollutant levels obtained by modeling pollutant sources, alternative land uses, and management scenarios. For the Mountain Run TMDL, the Virginia water quality regulations (9 VAC 25-260-170) were used to define the applicable endpoint. The in-stream fecal coliform target for this TMDL is the 30-day geometric mean concentration of 200 cfu/100 ml, with 0% violations.

[1] For commonly used laboratory methods, bacteria count refers to the counting of bacterial colonies grown in laboratory culture from the water sample, with the assumption that each colony originates from a single viable bacterium. These units are referred to as “colony forming units” or cfu. For further explanation, see Standard Methods for the Examination of Water and Wastewater, APHA 1995.

2.0 WATERSHED CHARACTERIZATION

{tc \l1 "2.0 WATERSHED CHARACTERIZATION**}**

2.1 Land Use

{tc \l2 "2.1 Land Use**}**

DCR personnel interpreted a digital land use data layer from SPOT imagery as part of a 1996 Clean Water Act §319 study in the Mountain Run watershed coordinated by the Rappahannock-Rapidan Planning District Commission (RRPDC). That data layer included 23 categories of land use that were re-classified into 7 categories for use with the TMDL model. Table 2-1 shows the original land use interpretations and the 7 land use categories used in the Mountain Run model.

2.2 Water Quality Data

A variety of water quality monitoring data is available for the watershed: from DEQ monthly and quarterly monitoring at two sites, from the RRPDC §319 study at 10 different sites, and from several short-term monitoring studies conducted in conjunction with the development of this TMDL.

2.2.1 DEQ Water Quality Monitoring Data{tc "2.1 Selection of a TMDL Endpoint and Critical Condition" \l 2}

The Virginia Department of Environmental Quality (DEQ) collects samples for fecal coliform bacteria analysis at two locations in the Mountain Run watershed on a regular basis. An upstream site (MTN022.49) is the Route 522 Bridge near Yowell Meadow Park in the Town of Culpeper, which has been monitored on a quarterly basis since 1987. The outlet site (MTN000.59) is at the Route 620 Bridge near Mountain Run's confluence with the Rappahannock River, which has been monitored on a monthly basis since 1991. Figure 2-1 shows a time-series plot of monitored fecal coliform concentrations at both sites since 1991. The maximum detection limit of the fecal coliform analyses used by DEQ was 8,000 cfu/100 mL. The purpose of this procedure was to bracket, and test for, the instantaneous state standard of 1,000 cfu/100 mL, and not necessarily to measure the actual value of the highest concentration. Therefore, values shown as 8,000 are actually unknown values greater than 8,000. Repeated violations have been detected at both stations. The most recent assessment period for the1998 303(d) report was between July 1, 1992 and June 30, 1997. During this period, the upstream site recorded 2 violations out of 17 samples for a 6% violation rate of the state water quality standard (WQS), while during the same period, the outlet site reported 12 violations out of 48 samples for a 25% violation rate. A listing of fecal coliform concentrations for individual DEQ samples from these two sites is in Appendix A.

Table 2-1. Mountain Run Watershed Land Use Category Groupings

TMDL Land Use Categories	Pervious/Impervious (Percentage)[1]	DCR Land Use Categories[2] (Class No.)
Cropland	Pervious (100%)	Row Crop (2110) Gullied Row Crop (2111) Row Crop Stripped (2113) Rotational Hay (2114) Nurseries (222)
Pasture	Pervious (100%)	Improved Pasture/Hayfield (2122) Unimproved Pasture (2123) Overgrazed Pasture (2124) Grassed waterways (2115) Recently Harvested Woodland -clear cut (41) Grazed Woodland (43) Transitional/Disturbed Sites (7) Unmanaged grass or shrubby areas (3)
Built-up	Pervious (60%) Impervious (40%)	Built-up <50% porous (11) Built-up >50% porous (12)
Rural Residential	Pervious (100%)	Wooded Residential (44) Rural Residential (14) Farmsteads without Animal Waste Facilities(13)
Loafing Lots	Pervious (100%)	Loafing Lots (2312) Farmstead with Dairy Waste Facilities (813) Large Individual Dairy Waste Facilities (8) Farmsteads with Animal Waste Facilities(13)
Forest	Pervious (100%)	Forest Land (40)
Lakes[3]	Pervious (100%)	Water (5)

[1]Land uses are classified with pervious and impervious components in the model.
[2]Original classification by DCR-DSWC from 1992 SPOT imagery and 1994 USDA/FSA aerial slides.
[3]The three major reservoirs are classified as lakes. All other waterbodies were reclassified to their surrounding land use.

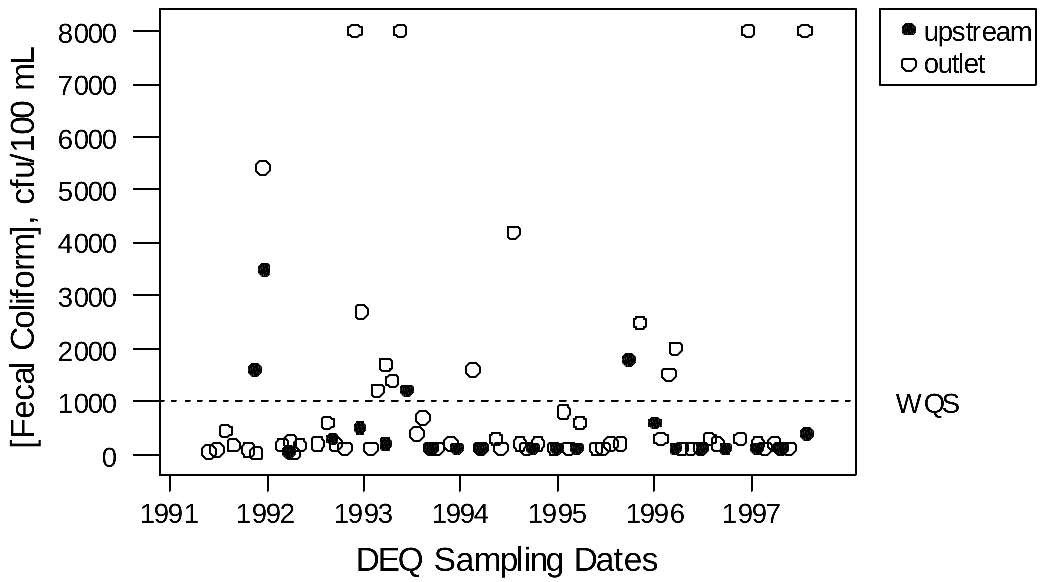

Figure 2-1. DEQ Fecal Coliform Concentrations at Mountain Run over Time

Although flow is not recorded at either of these sites, a U.S. Geological Survey (USGS) flow gage (01665000) was maintained in the watershed until October 1997, 3.0 miles west and upstream from the Town of Culpeper near the State Route 641 Bridge. Flow at this station fairly well represents flow trends in the watershed, although flows at the outlet will be greater. Figure 2-2 shows the distribution of fecal coliform concentrations for both of the DEQ sites and corresponding flow at the upstream USGS gage. A natural break in the data at 27 cfs was used to classify flow as lower or higher. For the upstream site, all reported WQS violations occurred at flows less than 27 cfs. At the outlet site, violations occurred during both low and high flows. Samples taken at the outlet site that corresponded with high flow almost always were in violation of the standard. At lower flows, violations still occurred, but with less frequency, and apparently unrelated to flow conditions. High concentrations during high flow are generally related to pollutant loads transported to streams by surface runoff, while high concentrations during low flow indicate sources contributing directly to the stream itself. Therefore, it is likely that different types of sources and transport mechanisms are operating in the upstream and downstream portions of the watershed. It should also be noted that during low flow, high concentrations can be produced by relatively small loads.

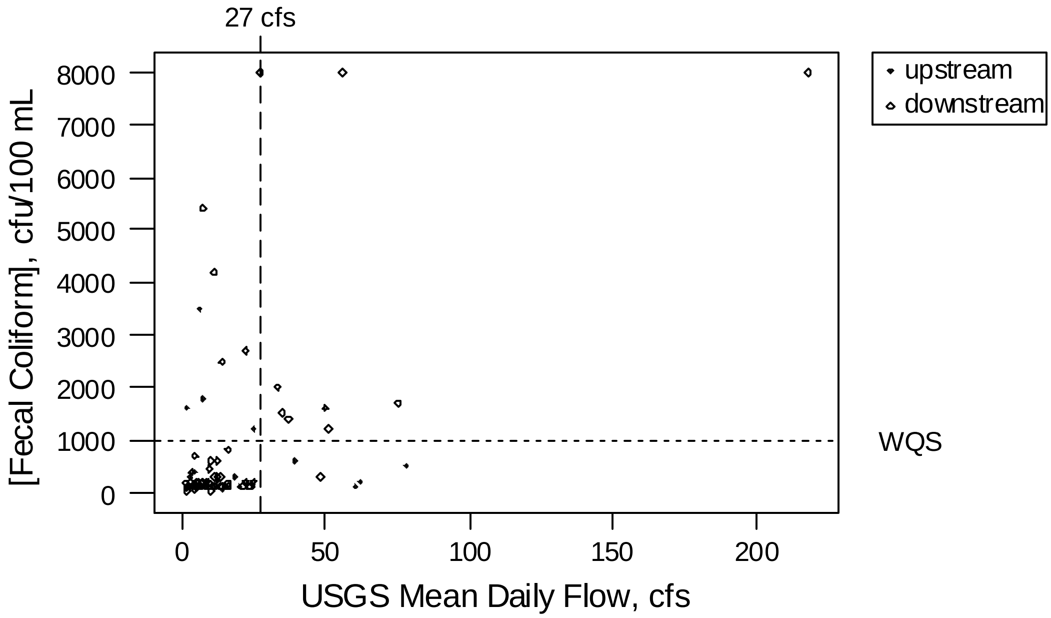

Figure 2-2. DEQ Fecal Coliform Concentrations vs. USGS Mean Daily Flow, 1991-1997

2.2.2 RRPDC Water Quality Monitoring Data 1996-1997

In 1996, the Rappahannock-Rapidan Planning District Commission (RRPDC) received a 2-year §319 grant from the Virginia Department of Conservation to begin data collection for subsequent TMDL development in the Mountain Run watershed. The RRPDC grant provided for additional monitoring in Mountain Run in order to assess the spatial distribution of fecal coliform concentrations within the watershed. The monitoring plan was developed and coordinated by the Biological Systems Engineering (BSE) Department at Virginia Tech. Ten monitoring sites were selected around the watershed, to represent approximately equal contributing surface areas. These sites and their corresponding sub-watersheds are shown in Figure 2-3. In order to provide continuity with historical data, sites 1 and 11 were chosen to correspond with DEQ's upstream and outlet sites, respectively, and site 3 to correspond with the USGS flow gage station. Each site was hand-sampled on a monthly basis and corresponded primarily with ambient conditions. Samples were collected, processed, and analyzed using EPA-approved quality assurance/quality control (QA/QC) procedures in the Water Quality Lab in the BSE Department. Fecal coliform bacteria were present in all but 4 samples out of a total of 145 samples taken throughout the watershed between October 1996 and December 1997. The ranges of fecal coliform concentrations at each monitoring site are illustrated as box plots in Figure 2-4.

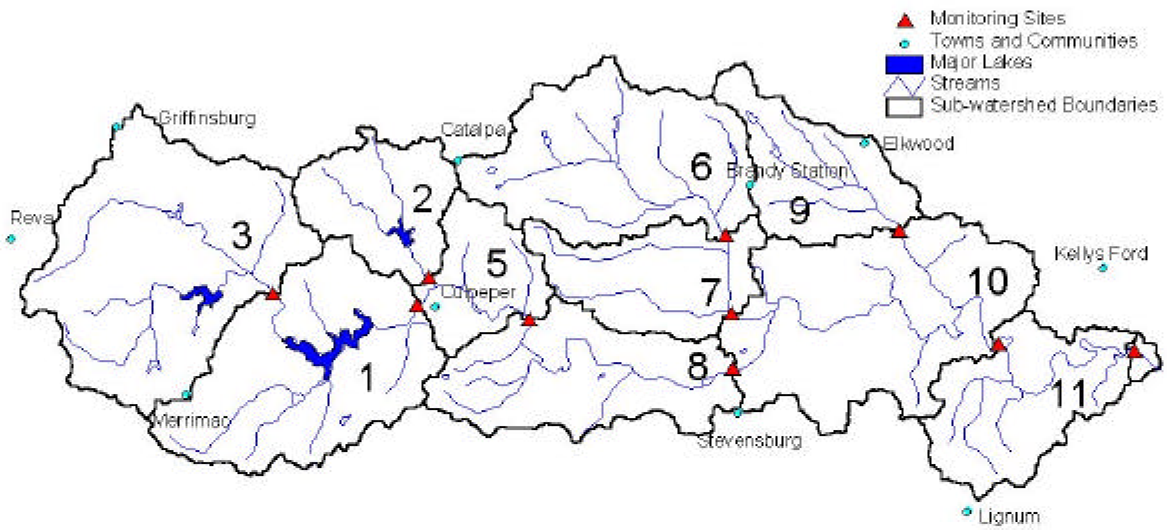

Figure 2-3. RRPDC First Year Monitoring Sites and Sub-watersheds

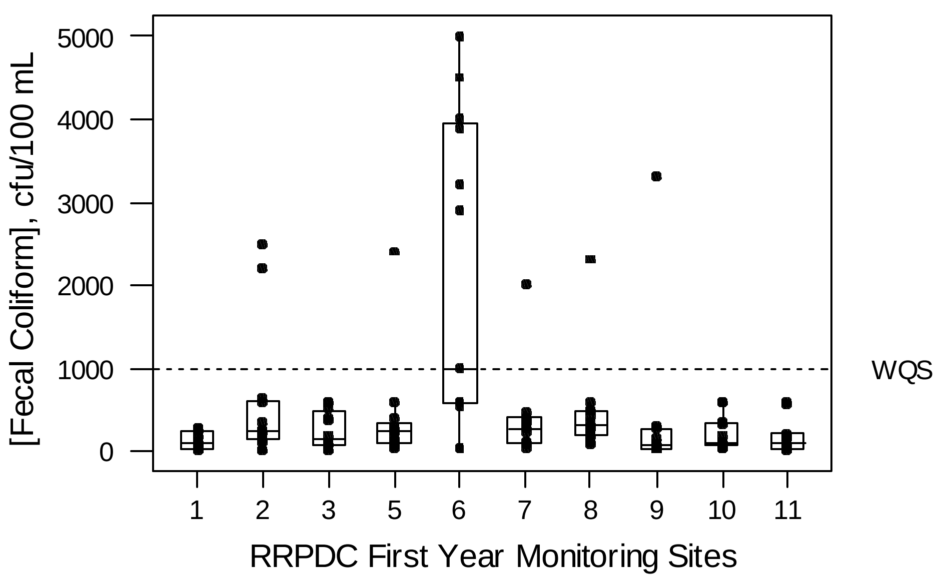

Figure 2-4. Ranges of RRPDC Fecal Coliform Concentrations by Sub-watershed: 1996-1997

The fecal coliform concentrations at site 6 were consistently higher than at all other sites, and most samples at site 6 violated the state standard. The high concentrations at site 6 appeared to be localized during base flow conditions and only affected downstream concentrations during the one sampling where stream levels were elevated from several days of rain prior to sampling. However, during this same period DEQ measured two violations at the outlet as shown in Figure 2-5. Both DEQ and RRPDC took monthly samples at the outlet, not on the same dates, but within a maximum of 2 weeks of the samples taken by the other agency. Split sampling was performed during one occasion for comparison of handling and analysis procedures. The analytical procedures used by the two labs were identical, and the results between the two labs showed only minor, expected variations. Despite these similarities, differences remained in reported fecal coliform concentrations, and resultant violations of the WQS, by the two agencies. These differences could be attributed to sampling variability, to variations in flow, to diurnal responses of the bacteria to environmental conditions, to local disturbances to stream sediments, and to human error.

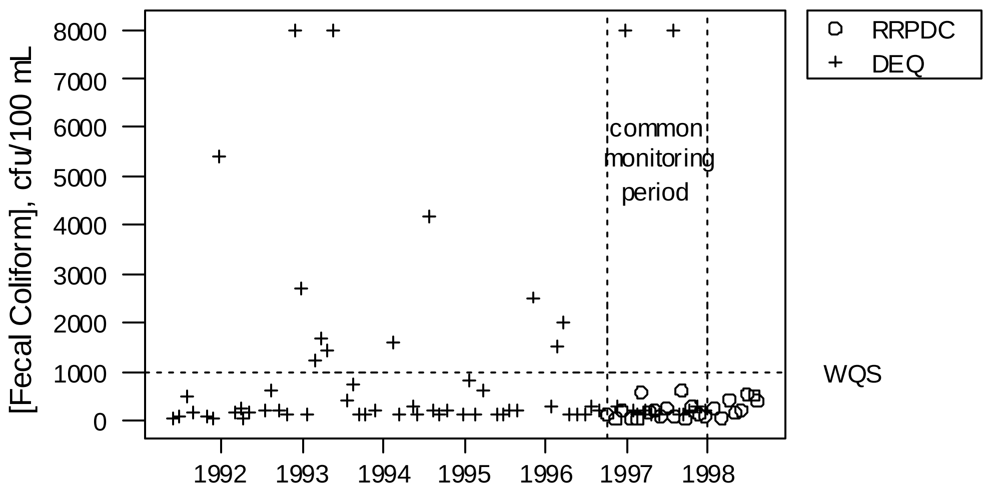

Figure 2-5. Comparison Between DEQ and RRPDC Monitored Fecal Coliform Concentrations

2.2.3 RRPDC Water Quality Monitoring Data 1997-1998

The monitoring configuration was changed in the second year, basically to monitor those sub-watersheds with one or more fecal coliform standard violations more intensively, with several exceptions. Flows at site 2 were fairly minimal, and since two other monitoring sites were close by, this station was discontinued. Station 7 was discontinued as the one violation reported there was attributed to loading from an upstream site (6) that was transported during storm runoff from recent rains. Site 9 was receiving such low flow, that a suitable upstream site with reliable flow could not be found. Therefore, the same site was continued. The monitoring sites in the second year are shown in Figure 2-6.

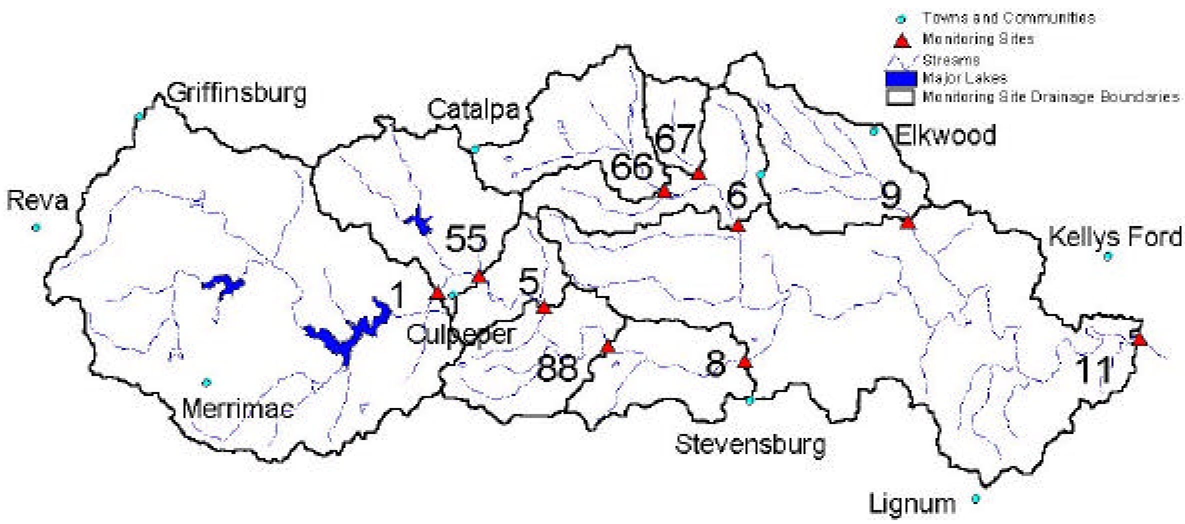

Figure 2-6. RRPDC Second Year Monitoring Sites and Sub-watersheds

The results of the second year of monitoring, as shown in Figure 2-7, continued to show high fecal coliform concentrations in sub-watershed 6, both of its contributing sites, and at site 9. A review of sampling conditions showed that sites 66, 67 and 9 in Figure 2-6 often had very minimal flow and sometimes resembled ponded, not flowing conditions. One violation was again noted in sub-watershed 8, but no violations occurred upstream at site 88, which receives drainage from the Town of Culpeper and surrounding residential areas. A listing of all fecal coliform concentrations reported by RRPDC from 1996-1998 are listed in Appendix B.

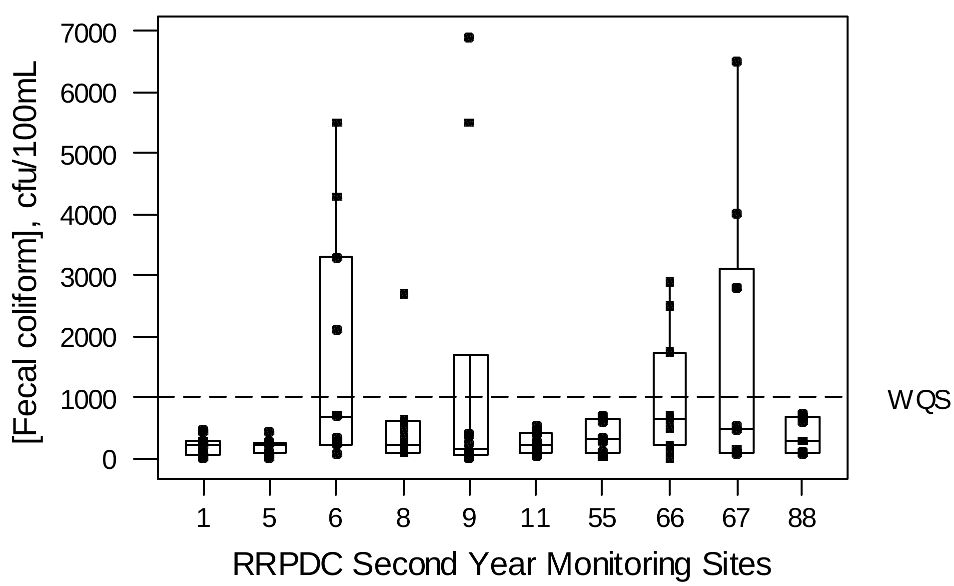

Figure 2-7. Ranges of RRPDC Fecal Coliform Concentrations by Sub-watershed: 1997-1998

2.2.4 Additional Water Quality Monitoring Data 1997-1998

Two areas of concern arose from the RRPDC study: the consistently high fecal coliform concentrations in sub-watershed 6, and the inconsistencies between DEQ and RRPDC results at the outlet. The historical data also indicated that violations at the outlet could be expected with runoff events, but monitoring had been for the ambient condition. An additional grant was secured from DCR to hand sample two runoff events at sites 6 and 11 and at multiple upstream contributing segments, as close together in time as possible. Seven additional sites were identified in sub-watershed 6 and three additional sites in sub-watershed 11, in order to further isolate contributing areas and/or the fecal coliform sources. One of the sites upstream from site 11 was monitored to isolate an overlooked tributary within the site 11 drainage. The arrangement of these additional monitoring sites is shown in Figure 2-8. Duplicate samples were collected for DNA analysis at select sites during the second event.

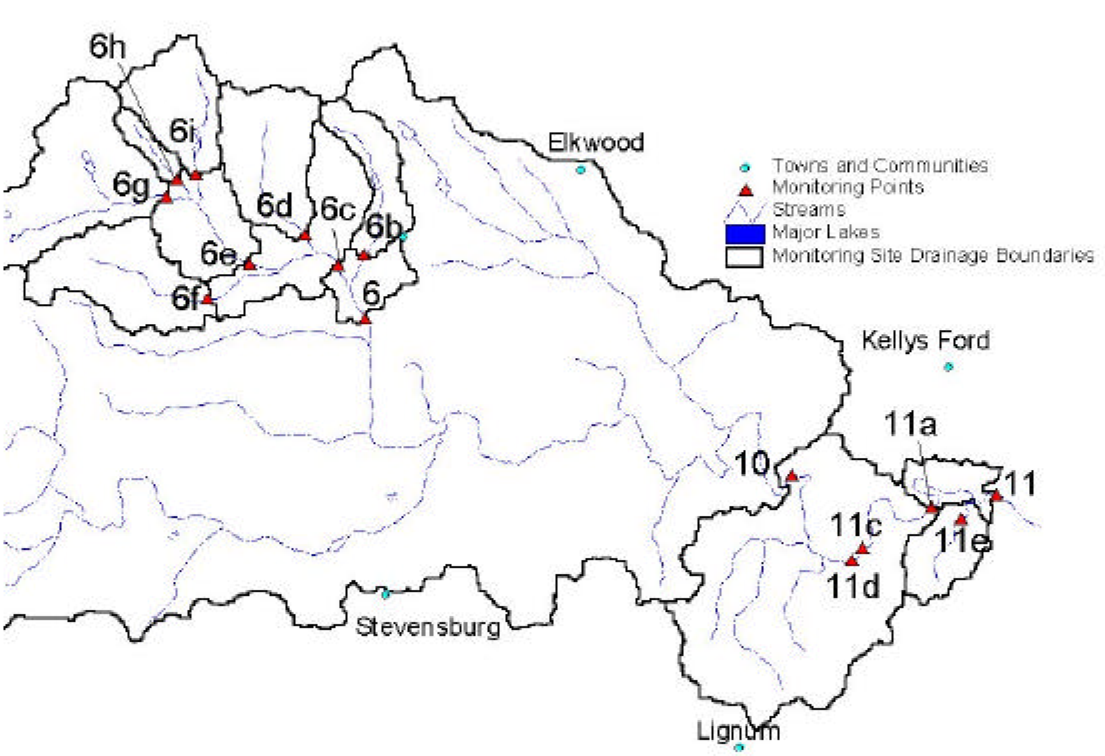

Figure 2-8. Additional 1998 Monitoring Sites

The first set of samples was collected from a storm runoff event on February 23, 1998. A second event was not captured during the allotted period of the grant and a 3-month extension was requested. Towards the end of the extension, a second runoff event had still not occurred, and a decision was made to sample regardless of rainfall. The second set of samples was taken on June 23, 1998, with all samples being collected within 1½ hours of each other. The weather had been hot and dry for an extended period of time. At many of the monitoring sites, the water was clouded and algae were present. The ambient sampling indicated WQS violations at 10 of the 15 sites.

Figure 2-9 compares the concentrations on a logarithmic scale from all sites on the two sampling dates. All sites that exceeded WQS during the runoff event also exceeded WQS during the ambient sampling, though generally to a lesser degree. Of the thirteen sites sampled on both dates, 6 sites reported higher concentrations during runoff, while 6 sites reported higher concentrations during ambient conditions, and one site was the same. All sites in sub-watershed 11 exceeded WQS during the ambient sampling. This also was the first time that a violation had been monitored at the outlet. The generally higher concentrations of fecal coliform during the ambient sampling were most likely explained by the growth of bacteria in the sediment, rather than indicating additional sources of bacteria. Growth conditions for bacteria were extremely conducive as indicated by the extended period of hot, dry weather, and the availability of nutrients, as indicated by the abundance of algae observed during sampling.

Duplicate water samples were gathered during the ambient condition at the four major source areas determined from the runoff sampling, along with the new site (11e), for possible DNA analysis. After performing the fecal coliform analysis to ensure sufficient bacteria for DNA analysis, four of the five samples were chosen for DNA analysis. The results of the DNA analysis will be discussed in the section on fecal coliform source assessment. A listing of fecal coliform concentrations from these additional 1998 samples are listed in Appendix C.

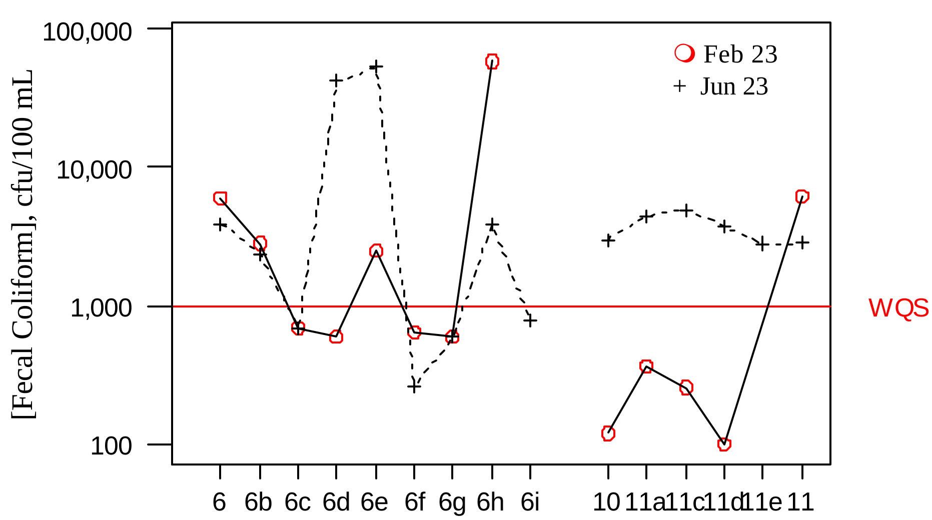

Figure 2-9. Fecal Coliform Concentrations By Date and Monitoring Site

2.2.5 TMDL-Related Water Quality Monitoring Data 1999

Monitoring was performed during the TMDL development phase to investigate the relationships between in-stream fecal coliform concentrations and flow, and between water column and channel sediment fecal coliform concentrations. Ten sites around the watershed were chosen from previously monitored sites, as shown in Figure 2-10, and were sampled on a monthly basis. Among these sites was site 11e, chosen to represent background concentrations. DNA samples were collected and analyzed from the headwater stream reaches where previous monitoring indicated high fecal coliform concentrations. Channel cross-sectional area and flow measurements were taken in conjunction with ambient sampling whenever conditions permitted.

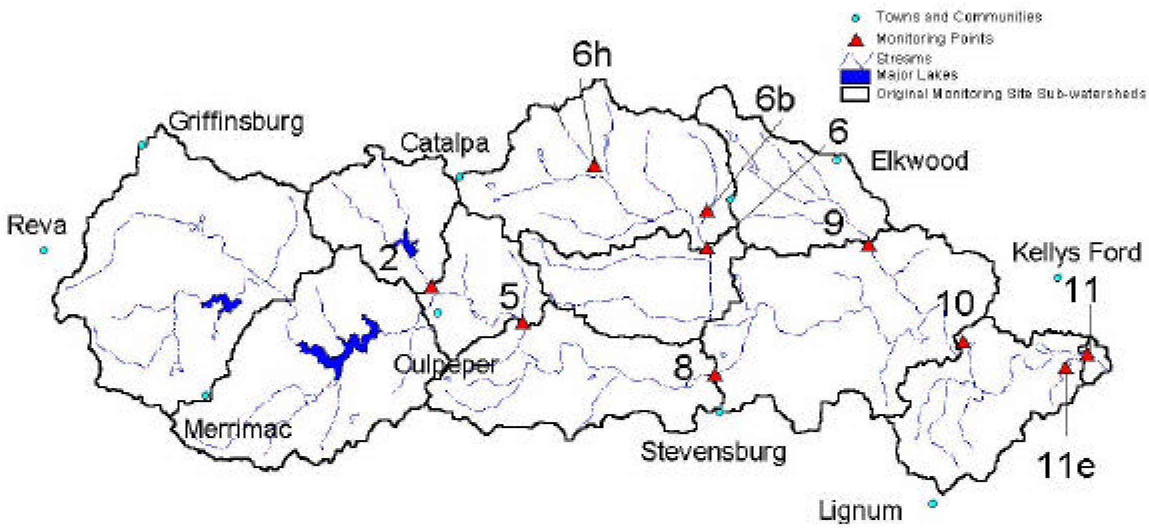

Figure 2-10. TMDL Study Monitoring Sites and Sub-watersheds

A total of 45 water column samples were collected and analyzed along with field blanks and duplicates collected as part of the QA/QC protocol. The fecal coliform concentrations measured during the TMDL study are summarized in Figures 2-11 and 2-12, and are listed individually in Appendix D. Five water quality standard exceedances were included at four different sites in the watershed. Three of the exceedances were reported on the same date, during elevated flow following rainfall on the previous day. The other two exceedances were from the same station, 6b, both sampled under no-flow, pooled conditions, and may represent in-stream bacterial re-growth rather than watershed inputs.

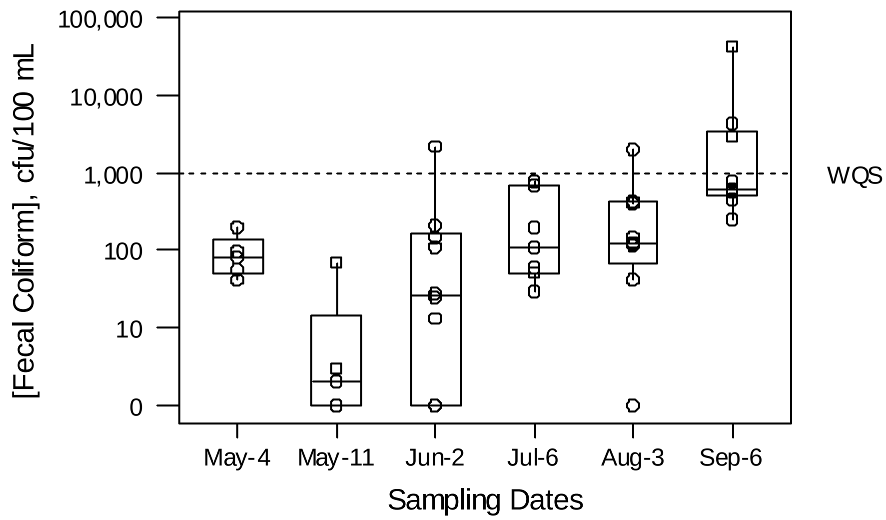

Figure 2-11. TMDL Study Monitored Fecal Coliform by Sampling Date

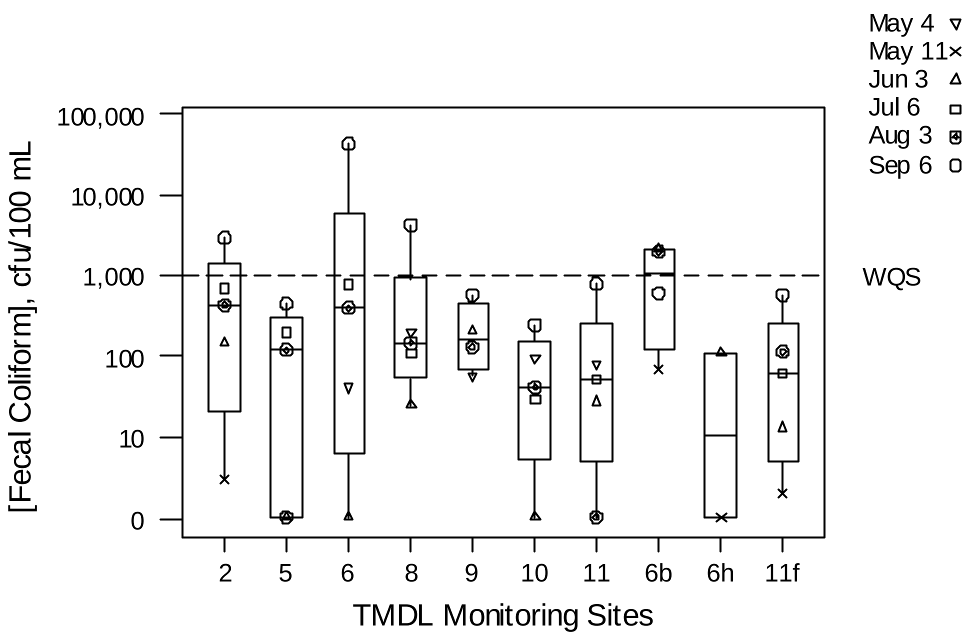

Figure 2-12. TMDL Study Monitored Fecal Coliform by Monitoring Site

Additional samples were collected in response to comments received during the first public meeting for the Mountain Run TMDL on June 2, 1999 in Culpeper. A recommendation was made to explicitly sample storm runoff from urban impervious areas in order to better assess the fecal contribution from this source. The Culpeper SWCD identified two outlets receiving storm runoff from impervious areas around the Town of Culpeper, and coordinated runoff sampling from these locations. One runoff event was sampled during this mostly dry period on July 22, 1999. A sample was collected from each site for fecal coliform analysis, and a third sample was collected for DNA analysis. Fecal coliform concentrations of 4,400 and 5,900 cfu/100 mL were reported for these samples, both exceeding the state water quality standard.

2.2.6 Summary of Water Quality Data

- High flows generally produced [FC] exceeding state water quality standards (WQS).
- Violations of the WQS were reported during both ambient and runoff conditions.
- Fecal coliform concentrations were observed to fluctuate over a wide range within short periods of time.
- Ambient, instantaneous [FC] for the background site were in the range of 2-590 cfu/100 mL.
- One series of samples produced extremely high [FC] at all stations during an extended hot, dry period, possibly due to bacterial re-growth, though this condition has not been verified or observed with other monitoring data.
- Many of the samples with high [FC] were collected under ambient conditions with very little, if any flow, and may not be representative of contributions from sources modeled in this study. In one area of the watershed that produced many of these samples, downstream concentrations were influenced by the higher upstream concentrations only during the one sampling where stream levels were elevated from several days of rain prior to sampling.
- Fecal coliform was detected in all but 4 samples out of 145 samples collected by the RRPDC between October 1996 and December 1997 from various sites around the watershed. DEQ detected fecal coliform in all of the 65 water samples that it collected from the watershed outlet over the past 6½ years, 14 of those samples being in violation of the state instantaneous fecal coliform standard.

3.0 SOURCE ASSESSMENT OF FECAL COLIFORM

3.1 Point Sources

Four municipal and industrial facilities are located in the watershed with permitted fecal coliform discharges. The permitted limits of daily flow and fecal coliform concentration for each facility are shown in Table 3-1. The Culpeper wastewater treatment plant (WWTP) is the only one of these four that is currently discharging into Mountain Run. Two of the other facilities have not yet been built, and one is currently off-line.

Table 3-1. VPDES Permitted Dischargers in the Mountain Run Watershed

VPDES	Facility Name	Stream	Permitted Daily Flow[1]	Permitted Fecal Coliform Concentration[2]	Status
VA0061590	Town of Culpeper WWTP	Mountain Run	3.0 MGD	200 cfu/100 mL	In operation
VA0062529	Ferguson WWTP	Jonas Run	0.0025 MGD	200 cfu/100 mL	Currently off-line
VA0087149	Mount Dumplin WWTP	Flat Run	0.3 MGD	200 cfu/100 mL	Facility not built
VA0090212	Mountain Run WWTP	Mountain Run	0.3 MGD	200 cfu/100 mL	Facility not yet built

[1] Monthly-averaged.
[2] 30-day geometric mean.

All of the wastewater treatment plants (WWTP) permitted in Mountain Run are required to use advanced secondary treatment, which removes fecal coliform from the wastewater discharge. Fecal coliform is only contributed from WWTP with secondary treatment in those cases where the treatment plant handles combined storm and sewer flows, and their treatment capacity is exceeded. Only one WWTP in the Mountain Run watershed is currently in operation, operated by the Town of Culpeper. The Town does not combine their storm flow with sewer flow. Secondary treatment at this facility has never been bypassed since 1983, according to the plant manager, when the plant increased its capacity to 3.0 MGD and tertiary treatment was installed. In Mountain Run, the WWTP does not appear to be a contributing source to downstream fecal bacteria levels.

3.2 Nonpoint Sources

3.2.1 Livestock Inventory

A survey of major livestock farms in the Mountain Run watershed was conducted in 1997. The Rappahannock-Rapidan Planning District Commission (RRPDC) conducted this survey in conjunction with a Clean Water Act §319 watershed grant from the state. This survey included information on the type, number and average weight of livestock on each farm, along with estimates of hrs/day spent in loafing or confinement areas, hrs/day with access to a stream, and percentage of manure collected and spread. This information was supplemented with discussions with local NRCS, VCES and SWCD personnel. Since livestock population fluctuates from year to year, a windshield survey was performed in the summer of 1999 to update the previous inventory and to account for smaller operations as well. Livestock totals for the watershed were defined in terms of animal units (1 AU equals 1,000 lbs) as follows: 3,192 beef, 2,073 dairy, 45 swine, and 128 horse.

3.2.2 Septic System Analysis

Properly installed and maintained septic systems are designed to properly treat waste and should not contribute fecal coliform to streams. However, improperly installed or maintained systems, and those rural residences without a septic treatment system, represent potential sources of human fecal coliform within the watershed. The year 1978 (20 years ago at the start of this project) was chosen in consultation with the local Health Department to represent a starting point after which newly installed septic systems would have been built to regulated specifications that represent a proper installation. Septic systems installed prior to this time were less likely to be permitted and were treated as sources of fecal coliform as detailed in Section 4.4. A total of 286 problem septic systems or sewage disposal sites were identified in the Mountain Run watershed. These problem systems were explicitly defined as:

- 207 septic systems installed more than 20 years ago (treated as system failures), and
- 79 house locations without corresponding septic system or access to public sewer (treated as straight pipes).

Age of septic systems was identified from paper files in the Culpeper office of the Virginia Department of Health (VDH) for locations plotted on topographic maps by VDH personnel. Septic system locations were manually identified and plotted by VDH personnel onto USGS 7½" topographic maps. These maps were subsequently digitized for use with the ArcView GIS. From this information, 530 individual and 37 group septic systems were identified in the watershed. Later in the process of evaluating the potential of septic systems to contribute fecal coliform to streams, the age of systems was determined to be an important factor. This information was not collected during the initial location identification procedure, so paper files were revisited at VDH, where age of system was obtained from individual VDH-approved septic system applications. Tax maps were obtained from the Culpeper Department of Development. These were used to cross-reference the septic system locations with a manual tax map grid used by VDH. These locations were then used to identify the proper file folder referenced by tax map grid coordinates that contained the individual applications.

Houses with potential straight pipes were assessed by matching identified system locations with address locations from a digital E-911 map for the county, and then further evaluating the unmatched addresses. Addresses were removed from this list if they were recently-built residences, were associated with a sub-division, had access to public sewer lines, or were non-residential buildings. "Access to public sewer" by individual homes near the Town's boundary was estimated from the "Sewer Mains and Facilities" map in the Culpeper 21 Plan (Town of Culpeper, 1994).

3.2.3 Wildlife Inventory

The total contribution from wildlife, the "natural" source of fecal material or scat, is unknown. However, populations of raccoon, muskrat, ducks, geese, beaver, and deer are known to exist in parts of the watershed. Large accumulations of scat have been observed on rocks and horizontal tree trunks within the stream corridor near the watershed outlet. Beaver activity has been reported as increasing in one sub-watershed, and flocks of migratory waterfowl are seasonally present around some ponds.

Five types of wildlife were considered significant contributors of fecal coliform in the watershed – deer, ducks, geese, muskrats, and raccoons. Beaver was not included since the measurement of fecal coliform in a beaver scat sample was orders of magnitude smaller than other wildlife sources (Appendix G). Wildlife populations were calculated from estimates of suitable habitat and estimates of population densities supported within suitable habitat areas, as shown in Table 3-2.

Suitable habitats were defined in consultation with Virginia Department of Game and Inland Fisheries (VDGIF) personnel and then spatially generated and measured in ArcView GIS. Suitable habitat areas were defined for individual wildlife species as follows:

- deer: all forested areas and adjacent land parcels.
- ducks: all forested areas within 400 meters (~¼ mile) of perennial streams.
- geese: all areas within 100 meters of surface water impoundments and Yowell Meadow Park, excluding wooded and residential areas.

- muskrat: all forested areas within 10 meters of perennial streams.
- raccoon: all areas within 400 meters of perennial streams, excluding loafing lot and pasture areas.

The population densities within suitable habitats used in this study are listed below for individual wildlife types:

- deer: Piedmont whitetail population estimate (Halls, 1984); 31/sq.mi. = 31/640 acre = 1/20.65 acre.
- duck: personal communication with Dan Lovelace, VDGIF.
- goose: calculated from suitable habitat areas, and population estimates by local Soil and Water Conservation District and USDA-NRCS personnel.
- muskrat: estimate of lodge density, 2.5/ha ≈1/ac (Giles, 1987),

  and an average of 5 muskrats/lodge cited in Kator and Rhodes, 1996.
- raccoon: Giles, 1992.

Table 3-2. Wildlife Population Summary

Data Type	Units	deer	duck	geese	muskrat	raccoon
A. suitable habitat	acres	30,328	5,568	1,101	258	15,272
B. population density	no./acre	0.04844	0.04	0.455	5	0.07692
C. population	no. of animals	1,469	223	500	1,289	1,175

3.2.4 Urban Area Sources

Urban impervious areas contribute fecal coliform loads during storm runoff. Several storm water drains from the Town of Culpeper empty into the upper end of Yowell Meadow Park, and water samples collected in that area primarily reflect the influence of the surrounding and upstream urban area. The major impervious area in the watershed is the Town of Culpeper, though many of the surrounding sub-divisions, businesses and industries also contain impervious areas. The majority of the runoff from impervious areas in the Town of Culpeper bypasses the Town's wastewater treatment plant (WWTP) and, therefore, contributes to in-stream fecal bacteria concentrations. Similarly, runoff from parking lots, sub-divisions, and other impervious areas outside of the town limits are likely to contain fecal material from a variety of sources, including domestic cats and dogs, birds and rodents.

3.3 Source Assessment from Supplemental Monitoring

Supplemental monitoring was performed in conjunction with the development of this TMDL to assist in assessment of the various potential sources, and to provide some additional measurements of fecal coliform from suspected sources, with which to compare reported values from other areas.

3.3.1 DNA Analysis

Stream samples are generally taken from well-mixed portions of flowing water, and the assumption is that fecal coliform will be dispersed throughout the flow as is assumed for other pollutants, but this may not be the case with bacteria. The distribution of fecal coliform within a flowing stream and the distribution of fecal coliform from a given source within the stream are both unknown. Therefore, the representativeness of the various contributing sources within any given sample taken from the stream is questionable. The DNA analysis of a water sample can identify sources whose DNA is included in the sample (provided the source is included in the comparison samples), but it cannot prove which sources are not present, because of the uncertainties in fecal coliform distribution in the stream environment. A lack of detection of DNA from a specific source within a sample does not prove its absence in the stream. The DNA analysis was performed to provide an indication of links between known sources in the watershed and our monitored concentrations of fecal coliform in streams. Eighteen samples of fecal material were collected for DNA analysis from known species of livestock and wildlife around the Mountain Run watershed, and added to the Virginia Tech DNA Library. Fourteen unknown source samples were collected from streams in the watershed for DNA analysis as duplicates of monthly ambient samples and one runoff event at five of the monthly monitoring sites. Four unknown samples had previously been collected from monitoring sites during the RRPDC study. All DNA analyses were performed by the Virginia Tech Biology Department. Source identification was performed by matching spectral bands of *E. coli* DNA in stream samples from unknown sources with the DNA patterns of *E. coli* from known samples in the Virginia Tech DNA Library. The matching criteria used for this analysis were 1) that individual DNA spectral bands be within 10 units of the comparison band to be considered matched, and 2) that overall, 80% or more of the individual bands matched. Table 3-3 summarizes the number of DNA samples, the number of positive *E. coli* isolates identified out of 10 isolates / sample, and the number of matches with the current DNA library.

Table 3-3. Summary of DNA Matching Analysis

Distribution of DNA Isolates	RRPDC 1998	TMDL 1999	Total
Total Isolates/Study (DNA Samples x 10 isolates / sample)	40	140	180
No. of Isolates not used[1]	6	28	34
No. of Isolates with *E. coli* DNA strains (includes duplicate strains)	34	112	146
No. of Unique *E. coli* DNA strains	27	52	79
No. of Unique strains Matched with Va Tech DNA Library	19	34	53
Percent of Unique *E. coli* strains with Library Matches	70.4%	65.4%	67.1%

[1] These isolates were smeared, the DNA strands did not properly cut during extraction, or were identified as bacteria other than *E. coli*.

A complete listing of isolates is given in Appendix E and of matching sample categories in Appendix F. The results of the DNA analysis support the supposition that all of these potential sources contribute in some degree to in-stream concentrations. The analysis cannot be used, however, to quantify the amount of fecal coliform that can be apportioned to each source. Figure 3-1 illustrates the wide variety of DNA "fingerprints" detected from the various sampling locations.

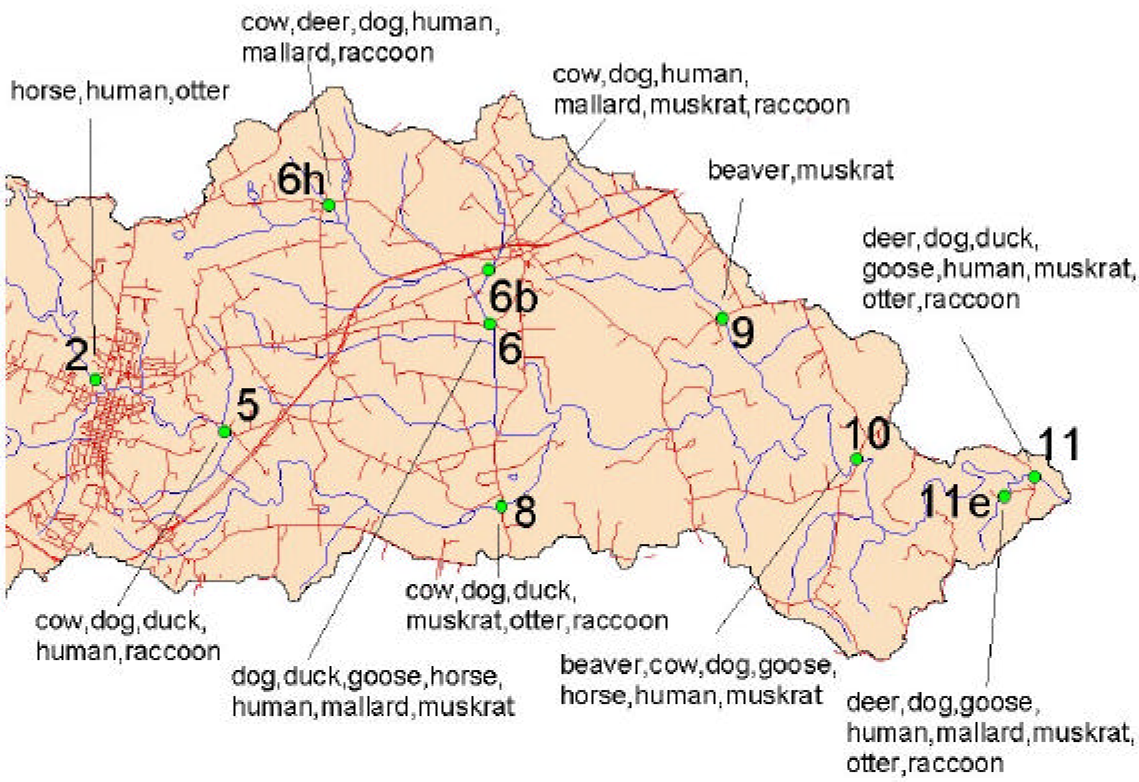

Figure 3-1. DNA Probable Sources from Various Sampling Locations

3.3.2 Sediment/Water Column Sampling

During the TMDL study in 1999, sediment samples were collected at the same time that the water column was sampled at each monitoring site. A representative site of sediment deposition was located upstream from each monitoring site. Each sediment sample consisted of several sub-samples collected with a sterile spoon in the representative area and composited. Sediment samples were separated into three particle size fractions, treated with a surfactant, and blended with a sterile phosphate buffer solution in appropriate decimal dilutions for fecal coliform analysis. Because channel conditions were not always conducive to sampling the channel bottom (when the stream was flowing too fast, or the water was too murky to see the bottom) only 36 sediment samples were taken together with the 45 water column samples. Table 3-4 shows a comparison of the 36 corresponding sediment and water column samples. For this analysis fecal coliform were reported for total sediment and not for individual particle size fractions. The fecal coliform density was measured as the total of all coliform counted in solutions associated with a 10-mL sub-sample of wet sediment taken from each thoroughly mixed sample. Each sub-sample was weighed and the fecal coliform density calculated as the total number of fecal coliform colonies extracted in the solution from the sediment associated with the 10-mL sub-sample. For comparison with the fecal coliform concentration in the water column, a pseudo-concentration of fecal coliform associated with the sediment was calculated by dividing the total number of colonies by 10-mL and converting into comparable units. The average concentration of fecal coliform in the sediment was roughly 250 times greater than in the water column.

Table 3-4. Corresponding Water Column and Channel Sediment Fecal Coliform Concentrations

Date	SiteNo	Water [FC] (cfu/100 mL)	Sediment [FC] (cfu/100 mL)	FC Density (cfu/gram)
05/04/99	11	82	43400	*
05/04/99	10	96	3700	25.0
05/04/99	9	57	25400	226.8
05/04/99	8	200	1100	*
05/04/99	6	41	8800	69.8
05/11/99	11f	2	3400	19.5
05/11/99	6h	0	70600	678.8
05/11/99	6b	70	44000	305.6
05/11/99	5	0	30000	187.5
05/11/99	2	3	18200	161.1
06/03/99	11f	13	600	4.5
06/03/99	11	27	17900	100.0
06/03/99	10	0	5600	32.4
06/03/99	9	210	22400	128.7
06/03/99	8	25	2100	13.4
06/03/99	6	0	17100	93.4
06/03/99	6h	110	1200	10.4
06/03/99	6b	2200	20100	195.1
06/03/99	5	0	2600	16.3
06/03/99	2	150	2100	21.0
07/06/99	11f	62	184000	1076.0
07/06/99	11	52	192000	1066.7
07/06/99	10	30	25800	146.6
07/06/99	8	110	108000	631.6
07/06/99	5	200	18200	164.0
07/06/99	2	680	280000	2616.8
08/03/99	11f	114	86148	582.1
08/03/99	11	0	69186	372.0
08/03/99	10	42	19476	110.7
08/03/99	9	128	13242	93.3
08/03/99	8	146	184367	1104.0
08/03/99	6b	2000	11963	73.4
08/03/99	6	390	18358	116.2
08/03/99	5	120	67138	486.5
08/03/99	2	430	272123	2212.4
Averages		**228**	**55933**	**398**

* Sediment weights not recorded.

3.3.3 Manure Sampling

Part of the 1999 study in Mountain Run also consisted of sample collection and analysis to better characterize the contributions of fecal coliform bacteria from livestock waste. Samples were collected to characterize fresh livestock fecal material, animal waste in storage pits, in feedlots, and from manure as it aged over time in pastures, and in crop fields where animal waste had been spread after storage. In pasture areas, fresh deposits were identified, and positions marked, in order to repeat sampling the same deposit over time.

Selection of manure sampling sites and introduction to farmers with prospective sampling sites were both facilitated by Robert Shoemaker, DCR Nutrient Management Specialist. Darren Davis with the Virginia Department of Game and Inland Fisheries assisted in the identification of wildlife scat around the watershed for collection and analysis.

The number of samples taken from each farm was a function of the sampling schedule developed to assess the various animal types and the various locations around a farm where livestock manure can be found. This study was not comprehensive in nature, but was intended to provide numbers for comparison with literature values in assessing appropriate fecal coliform densities for developing the Mountain Run TMDL. Manure samples were collected in the field, refrigerated and transported to the laboratory for analysis. A small 20-gram portion of each sample was extracted, diluted with a buffered solution, and analyzed with a set of standardized procedures. These procedures involved taking a specific amount of sample and creating a series of sample dilutions. Within each dilution, a count of the viable, growing colonies translated into a bacteria count per volume of sample. Each dilution was capable of measuring the number of fecal coliform bacteria within a given range. The range of concentrations can be adjusted by the choice of dilutions used in the analysis. If the anticipated density is unknown or misjudged, the analysis can only state that the number is greater than (>) the range of the most dilute sample, or less than (<) the range of the most concentrated sample. Sample analysis in the early part of this study was not conducted with the anticipated density ranges in mind, resulting in the actual density not being quantified.

At the second public meeting, a question was raised why a value of 230,000 FC/gm was proposed for representing the fecal coliform density of beef and dairy manure, when that value was much greater than the values indicated by the highest sampled concentrations reported up to that point (>80,000 FC/gm). The answer was that the measured samples had not been diluted sufficiently to quantify the actual density. Since the actual density was known to be somewhat greater than the highest value measured, the published value of 230,000 was considered to be a more representative value. It was agreed that more confidence could be put into the sampled numbers if additional samples were taken and laboratory procedures specified to bracket the reported density of 230,000 FC/gram. Ten additional samples of livestock manure, therefore, were collected on October 27th and analyzed at dilutions to allow quantification and comparison with the previously cited fecal coliform density. Livestock manure densities from these samples showed a very large range. The highest densities exceeded the literature value of 230,000 cfu/gm reported by Geldreich (1977), as well as those calculated from the 1998 ASAE Standards of 1,840,000 and 4,940,000 cfu/gm for dairy and beef, respectively. Three samples had densities even higher than those which could have been enumerated within the chosen densities and are reported as > 8,000,000 cfu/gm. Analysis of these later samples support the position that values as high as 230,000 are appropriate for beef and dairy in the watershed, and indicate the use of an even higher value. Table 3-5 shows the range of fecal coliform densities by animal type for all fresh samples collected during the study. A listing of individual samples is in Appendix G.

Table 3-5. Summary of Fecal Coliform Densities in Fresh Livestock Manure Samples (FC/gram)

Animal Type	Count	Low	High	Average	Log-Average
dairy cow	5	3,500	> 8,000,000	1,778,300	107,470
dairy heifer	4	1,700	> 80,000	23,425	8,122
beef	6	65	> 8,000,000	1,360,775	10,410
swine	2	1,000	> 80,000	40,500	8,944
horse	4	100	25,000	6,400	562

Table 3-6 summarizes the samples that were taken to assess die-off under various livestock farm conditions. A time-series of samples was taken from each manure deposit over time (except for the storage samples) in order to quantify this die-off rate with time.

Table 3-6. Summary of Fecal Coliform Density Changes Over Time

	Beginning Date		Ending Date		Entire Study			
Sample Type	No. of Samples	Average FC Density (FC/gram)	No. of Samples	Average FC Density (FC/gram)	Study Interval (weeks)	No. of Samples	Average FC Density (FC/gram)	1st Order Die-Off Coefficient
pasture	4	> 42,875	2	< 400	19	16	13,707*	0.0351
manure storage	4	> 48,250	4	3,688	19	8	25,969*	0.0193
spreading areas	3	>27,633	3	< 1,787	3	9	9,946*	0.1304
feedlots	2	>80,000	2	> 80,000	19	6	> 58,250	0.0000

< = less than the lowest value in the range which the lowest sample dilution could evaluate.
> = greater than the highest value in the range which the highest sample dilution could evaluate.
* = average includes some detection limit values whose true value is actually either lower than, or greater than, the number being averaged.

Two types of averages are reported in the above tables, neither of which are true averages. Since many of these densities (25 out of 62) were reported as either greater than, or less than, a given number, the actual numbers were not available for averaging, adding a bias to the regular averages. Since three livestock samples were significantly greater than all of the others, a mathematical transformation, the log-average, was used to try and remove part of the accentuated bias in the average from these very large numbers. Neither average is wholly satisfactory on its own, but taken together, can give some perspective to the reported literature values.

3.4 Summary of Fecal Coliform Sources

The fecal coliform concentrations in Mountain Run are attributed solely to nonpoint sources. The known sources of fecal coliform are warm-blooded mammals: human, wildlife, livestock, and pets. DNA analysis was used to confirm that fecal coliform in the streams can be found from each of these sources at many locations around the Mountain Run watershed. The categories of fecal sources assessed for this TMDL include failed septic systems, “straight pipes”, wildlife, livestock manure both on the land surface and directly deposited in streams, and runoff from urban impervious areas. Samples of livestock manure and wildlife scat were collected during this study to provide perspective to literature values, especially where wide ranges of values have been reported. Table 3-7 provides a summary of the various values measured from the samples in this study, along with those found in the literature, and the values determined to be the most appropriate for modeling the animal sources of fecal coliform in Mountain Run. A high degree of variability was evident in the fecal coliform densities, even within a given animal type. Since this variability is expected, more emphasis is placed on ranges and averages than with individual values. The samples collected and analyzed during this study provided site-specific values for comparison with published values.

Table 3-7. Fecal Coliform Density Summary (FC/gram)

	Study Summary, April-October 1999				Various Published Values			
Animal Type	**No. of Samples**	**Density Range**	**Average**	**Log-Average**	**Geldreich, 1977**	**ASAE Standards, 1998**	**Others**	**Values Used for TMDL Modeling[1]**
dairy	9	1,700 - >8,000,000	998,356	34,103	230,000	1,840,000		1,143,000
beef	6	65 - >8,000,000	1,360,775	10,410	230,000	4,940,000		1,143,000
swine	2	1,000 - > 80,000	40,500	8,944	3,300,000	3,920,000		3,300,000
horse	4	100 – 25,000	6,400	562	12,600	23,000		12,600
biosolids	1	< 1					NR	
dog	1	45,000					23,000,000	
deer	1	450,000					170	450,000
goose	1	800,000					31,600 – 1,000,000	800,000
muskrat	1	250,000					340,000	250,000
raccoon	1	250,000					1,000,000,000	250,000
beaver	1	< 1,000					NR	
duck					33,000,000	16,230,000		16,230,000

NR = not researched, minor influence
< = less than the lowest value in the range which the lowest sample dilution could evaluate.
> = greater than the highest value in the range which the highest sample dilution could evaluate.

[1] 1,143,000 was calculated as an average of all beef, dairy and heifer samples collected and analyzed as part of this study.

4.0 MODELING FOR TMDL DEVELOPMENT

A key component in developing a TMDL is establishing the relationship between pollutant loadings (both point and nonpoint) and in-stream water quality conditions. Once this relationship is developed, management options for reducing pollutant loadings to streams can be assessed. In developing a TMDL, it is critical to understand the processes that affect the fate and transport of the pollutants and cause the impairment of the waterbody of concern. Pollutant transport to water bodies is evaluated using a variety of tools, including monitoring, geographic information systems (GIS), and computer simulation models. In this chapter, model description, input data requirements, model calibration procedure and results, and model validation results are discussed.

4.1 Model Description

TMDL plan development requires the use of a watershed-based model that integrates both point and nonpoint sources and simulates in-stream water quality processes. The Hydrologic Simulation Program – FORTRAN (HSPF) (Bicknell et al., 1997) was used to model fecal coliform transport and fate in the Mountain Run watershed. The BASINS interface (Better Assessment Science Integrating Point and Nonpoint Sources System) Version 2.0 (Lahlou et al., 1998) was used to facilitate use of HSPF. Specifically, the NPSM interface within BASINS provides pre- and post-processing support for HSPF. The ArcView 3.1 GIS provided the integrating framework for BASINS and allowed the display and analysis of landscape information.

HSPF is a lumped-parameter, continuous simulation model that simulates both point and nonpoint source runoff and pollutant loadings, performs flow routing through streams, and simulates in-stream water quality processes (Donigian et al., 1995). HSPF estimates runoff from both pervious and impervious parts of the watershed and simulates stream flow in the channel network. The sub-module PWATER within the module PERLND simulates runoff, and hence, estimates the water budget on pervious areas (e.g., agricultural land). Runoff from largely impervious areas is modeled using the IWATER sub-module within the IMPLND module. The simulation of flow through the stream network is performed using the sub-modules, HYDR and ADCALC within the module RCHRES. While HYDR routes the water through the stream network, ADCALC calculates variables used for simulating convective transport of the pollutant in the stream. Fate of fecal coliform on pervious and impervious land segments is simulated using the PQUAL (PERLND module) and IQUAL (IMPLND module) sub-modules, respectively. Fate of fecal coliform in stream water is simulated using the GQUAL sub-module within RCHRES module.

The BASINS software was used to extract data from digital GIS data layers for local streams, watersheds and land use to create the basic data for running the Hydrologic Simulation Program – FORTRAN (HSPF version 11) model. The non-point source model (NPSM) interface with BASINS was used to enter additional parameter values needed by the model.

The objective of the model for the Mountain Run watershed was to simulate in-stream fecal coliform concentrations in the impaired stream segment as measured at the watershed outlet. The model of the Mountain Run watershed focuses on the portion of the watershed downstream from Lake Pelham and Catalpa Lake. Research indicates that fecal coliform tend to settle out and die-off in larger reservoirs. Fecal coliform sources above these reservoirs, therefore, were ignored. Flow above Lake Catalpa was simulated in the model. Measured daily flow from the USGS flow gage on State Route 641 was directly input into the model, rather than simulating flow from the area upstream from Lake Pelham. Use of this procedure allows for a more detailed spatial delineation of land use and fecal coliform sources downstream within the limited resources of the model.

The original concept of the fecal coliform model for the Mountain Run watershed incorporated a sediment component. A preponderance of research indicates the presence of fecal coliform attached to channel sediment. Indeed, research conducted within the development of this TMDL showed sediment concentrations of fecal coliform approximately 250 times greater than in the water column. The relationship between these two is not well understood. One apparent fecal coliform re-growth episode, suspected of being related to fecal coliform attached to channel sediment, was monitored in the watershed, but a repeat event has never been observed or sampled since. A suggestion has been made recently that fecal coliform in channel sediment may die back completely in the wintertime, and may not serve as a carry-over reservoir of fecal coliform. An attempt to incorporate sediment in the model of Mountain Run watershed also revealed a large number of parameters that required field measurements that were not available for the watershed. Because of these remaining uncertainties in the role that sediment plays in in-stream fecal coliform concentrations, a decision was made not to include the sediment component explicitly in the Mountain Run model. Any contributions from this source, therefore, are indirectly accounted for within the fecal coliform calibration procedure.

A concern had been raised during one of the public meetings about backwater effects from the Rappahannock River during flooding. Since modeling this condition would entail a much larger modeling effort, and since the simpler relationship between upstream sources and in-stream concentrations has yet to be fully explored, this modeling effort will focus on exploring the simpler relationship. A larger, more detailed, costlier modeling effort would only be justified if the simpler relationship with upstream sources cannot be shown to account for outlet fecal coliform concentrations.

4.2 Selection of Sub-Watersheds

Loadings of fecal coliform are associated with the type of land-use activities and the degree of development in the watershed. Sub-watersheds were delineated based on an assessment of the spatial variation in fecal coliform sources and the distribution of land uses. Wherever possible, sub-watershed outlets were located at the confluence of two stream reaches.

For modeling purposes, the Mountain Run watershed was represented as 16 stream segments and 16 corresponding sub-watersheds as shown in Figure 4-1. The stream network was simplified to a single stream reach along the main channel in each sub-watershed for evaluation of stream characteristics in the HSPF model.

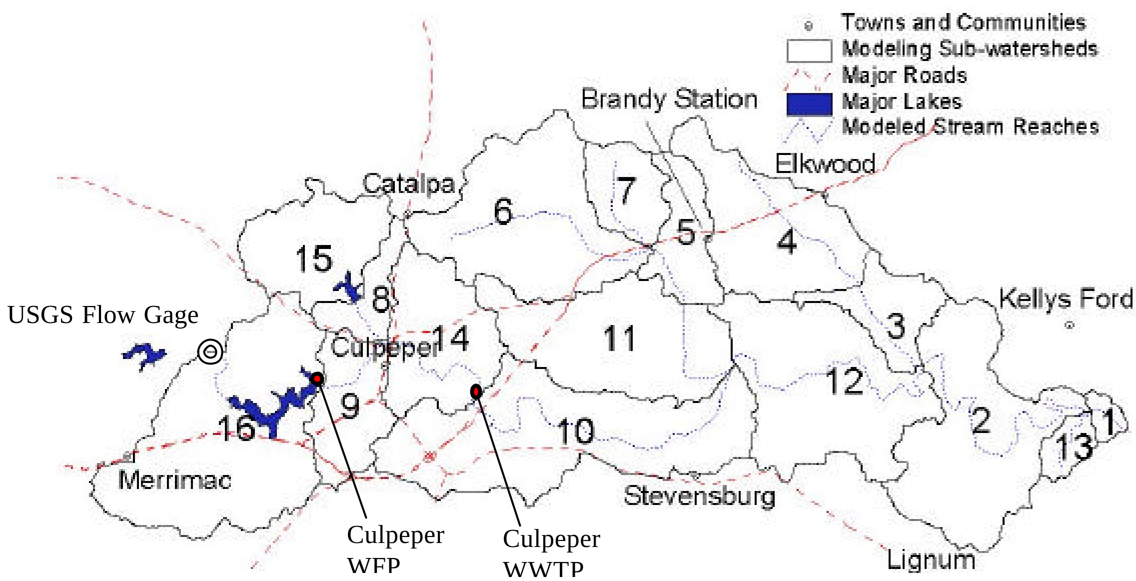

Figure 4-1. Mountain Run Watershed Modeling Stream Reaches and Sub-Watersheds

The NPSM interface does not allow reservoirs to be represented in the model, although the HSPF model has this capability. Since reservoirs have a pronounced effect on the hydrology in Mountain Run, procedures were followed as outlined in BASINS Technical Notes #1 and #4 to simulate both Lake Pelham and Caynor Lake explicitly as reservoirs outside of the NPSM interface (EPA, 1999a).

4.3 Input Data Requirements

The HSPF model requires a wide variety of input data to describe hydrology, water quality, and land-use characteristics of the watershed. HSPF is a lumped-parameter model that spatially averages parameters over each defined sub-watershed in the study area and allows for input of variable parameters, some by land use category, some by sub-watershed area, and others as time-series inputs by individual land use/sub-watershed combinations. The different types and sources of input data used to develop the TMDL plan for the Mountain Run watershed are discussed below.

4.3.1 Climatic Data

The closest meteorological station to Culpeper in the BASINS dataset is the Piedmont Research Station near Orange. A preliminary model run during the 1984-1994 period showed that rainfall from the Piedmont station did not always correspond with daily flow records from the USGS 01665000 station. A National Climatic Data Center (NCDC) cooperative observer station was found in Culpeper and was used as a more representative source of local hourly data for the Mountain Run watershed. Data for the period 1949-1998 was obtained from an NCDC archive site on the Internet. The Culpeper NCDC precipitation data set was edited and corrected based on the Culpeper cooperative weather station data, with missing data and data distributions supplied by the Remington, Elkwood and Piedmont Research Station hourly precipitation data sets. The Culpeper precipitation data has been incorporated into a WDM data set using the WDMutil software (EPA, 1999b), for use with the NPSM model interface in BASINS.

The other required climatic data were obtained from the Piedmont Research Station database within BASINS for the 1970-1995 period. Data for more recent modeling from 1996-1998 came from a variety of stations at the NOAA National Climatic Data Center web site (http://www.ncdc.noaa.gov):

- hourly precipitation (Culpeper).
- Daily Surface Data (Piedmont Research Station): minimum and maximum temperature, evaporation, and total wind.
- Daily Surface Data (Washington/Dulles): average windspeed, sky cover, and average dewpoint temperature.

Other required climatic data was derived from the above data through computation, or disaggregating into hourly intervals, using utilities within the WDMutil program (EPA, 1999b).

Three periods of data were required for development of the Mountain Run TMDL. The available rainfall data was checked for completeness of record and for periods that included a range of wet, dry and normal annual rainfall. Two such 4-year periods of record were identified. One set was used for hydrologic calibration and the other set for performing the modeling runs for TMDL allocation. Water quality calibration was performed during the time period where observed fecal coliform measurements were available. Hydrologic calibration was performed using rainfall data from January 1984 through December 1989; water quality (fecal coliform) calibration using data from January 1995 through September 1997; and the TMDL modeling using data from January 1979 through December 1983. The first two years of the hydrologic calibration modeling and the first year of the other modeling runs were used to initialize state variables within the model, and were not used for comparison with observed data or for assessment of the TMDL.

4.3.2 Daily Flow Data

Daily flow data was available for the USGS flow gaging station (01665000) located within the watershed on State Route 641, approximately 3 miles west of the Town of Culpeper. Data for this station was available from January 1979 through the end of September 1997, when gaging was discontinued.

Two additional flows within the watershed were accounted for in the model: daily withdrawals from Lake Pelham by the Culpeper Water Filtration Plant (WFP) used as water supply for the Town, and daily treated discharge from the Culpeper Wastewater Treatment Plant (WWTP) downstream from the Town into Mountain Run. Daily flows for these two entities were obtained from a combination of computer files and monthly paper reports for the period 1986-1989 from both facilities, and for the period 1996-1998 from the WWTP. Within the Mountain Run watershed during 1996-98, the WFP withdrew a daily average of 1.39 MGD from Lake Pelham for treatment and distribution to the Town of Culpeper. An average of 2.17 MGD returned to the WWTP for treatment and discharge back into Mountain Run. The difference in flows between the intake and discharge has been attributed to inflow and infiltration in the collection system.

Daily records for 1986-89 WFP withdrawals were unavailable, and so were reconstructed by developing relationships between daily withdrawals and discharges for the 1996-98 period and applying these relationships to the available WWTP daily flows. Since storm runoff was a significant influence on this relationship, monthly fractional averages of WFP withdrawals were calculated separately for days with, and without, precipitation, and applied to the available 1986-89 WWTP daily discharge.

Daily records for both WFP and WWTP were also constructed for a future scenario to correspond with 1979-1983 rainfall for modeling the TMDL allocations. Three major influences on future predictions of flow volume at both facilities are the population served, daily rainfall, and seasonal variability. The

1996-98 records of daily WFP and WWTP flows were used to create monthly averages for days with and without rainfall. Increased flow due to population growth was incorporated as annual flow increments separately for the WFP and the WWTP. Annual increments of +0.078 cfs/year for daily WFP withdrawals and +0.141 cfs/year for daily WWTP discharge were based on annual average flow from each facility during 1986-88 and during 1996-98. These monthly averages and annual increments were used along with the rainfall record to construct daily flows for WFP and WWTP for the 1979-1983 period.

4.3.3 Land Use

Land use data was used to evaluate the values of several hydrology and water quality parameters for the simulations. Table 4-1 shows the distribution of each of the 7 land use categories in each of the sixteen sub-watersheds, as well as watershed totals. Each combination of sub-watershed and land use was defined as a pervious land segment (PLS) in the model. Mountain Run was represented in the model with 89 PLSs, 12 of which included an impervious component.

4.3.4 Other Model Parameters

The hydrology parameters required by PWATER and IWATER were defined for every land-use category for each sub-watershed. For each reach in the watershed, a function table (FTABLE) was required to describe the relationship between water depth, surface area, volume, and discharge (Donigian et al., 1995). Hydrology parameters required for the PWATER, IWATER, HYDR, and ADCALC sub-modules, and general water quality (fecal coliform) parameters for the PQUAL, IQUAL, and GQUAL sub-modules are listed in Appendix B.1 of the BASINS 2.0 User's Manual (Lahlou et al., 1998). Runoff estimated by the model is also an input to the water quality components. Values for the parameters were estimated based on local conditions when possible, otherwise the default parameter values provided within HSPF were used.

PLSs have no spatial attributes within the model, except as an acreage total within one of the sub-watersheds. ArcView GIS was used to spatially define PLSs. These spatially-defined PLSs were then used in combination with digital soils and elevation data to derive some of the soils and topographic parameters associated with each PLS. Soil infiltration, average land slope, and average slope length were each evaluated in this manner.

Table 4-1. Land Use Distribution by Sub-Watershed (acres)

Sub-Watershed	pasture	forest	cropland	rural residential	loafing lots	urban developing	lakes	Total
1	46	91	76	44	0	0	0	257
2	1,185	2,433	1,085	156	8	0	0	4,867
3	273	672	351	50	7	0	0	1,353
4	741	982	1,490	174	11	100	0	3,499
5	432	110	684	62	7	106	0	1,401
6	1,838	614	1,743	374	10	134	0	4,713
7	396	68	731	24	16	2	0	1,238
8	205	131	221	79	0	234	0	870
9	486	37	24	5	0	1,259	0	1,810
10	1,460	863	3,210	177	68	310	0	6,087
11	1,407	294	2,044	266	27	118	0	4,156
12	1,291	2,482	1,030	81	25	43	0	4,952
13	20	401	38	16	0	0	0	474
14	855	271	484	93	0	1,040	0	2,743
15	1,071	588	292	186	13	239	47	2,436
16	2,831	1,739	449	420	6	783	220	6,449
Modeled Area	**14,537**	**11,777**	**13,952**	**2,205**	**198**	**4,369**	**268**	**47,305**
	30.7%	24.9%	29.5%	4.7%	0.4%	9.2%	0.6%	

4.4 Quantification of Fecal Coliform Sources

None of the VPDES-permitted point source dischargers report measurable fecal coliform concentrations in their discharge, so no fecal coliform loads are attributed to these point sources under the existing conditions in the Mountain Run watershed. Fecal coliform loads that are directly deposited by livestock in streams ("cows-in-streams") and homes without approved septic systems ("straight pipes") were represented as direct nonpoint sources in the model. These direct nonpoint point sources were summed by each source type in each sub-watershed and input directly as a point source to their respective stream reach. Fecal coliform that was land-applied or deposited on land was treated as nonpoint source loading. The nonpoint source fecal coliform load was reduced by die-off both during storage (external to the model) and after land application in the field. The nonpoint source loading was applied as monthly distributions of fecal coliform loads to each of the 89 PLSs. The nonpoint source fecal coliform load was transported to the stream as a function of rainfall amount and intensity. Both nonpoint and direct nonpoint source loadings were varied by month to account for seasonal differences. Computerized spreadsheets were used to facilitate the compilation of fecal coliform daily loads from the various sources into one matrix by PLS and by month.

4.4.1 Septic Systems

Daily fecal coliform (FC) loads from problem septic systems, previously defined as either septic system failures or “straight pipes”, were both calculated as:

Daily FC load = average FC production/person/day * no. of persons * SAF * DR

where average human FC production/day = 1.95 x 10^9 /day (Geldreich, 1977), and SAF, the soil attenuation factor, was assigned by the following septic tank absorption field limitations, a function of soil type (USDA-NRCS, 1996):

Severe limitation:	SAF = 0.90
Moderate limitation:	SAF = 0.70
Slight limitation:	SAF = 0.30

Since delivery is also dependent on distance to the nearest stream, a delivery ratio, DR, was structured so that DR = 1.00 adjacent to the stream, while systems located greater than 500 feet from the stream will have a DR = 0.0, with an exponential decrease between 0 and 500 feet, stated as:

$$DR = e^{-0.011*d}$$

where d = distance in feet to the nearest stream. Loads from septic system failures were applied to pervious land segments, while loads from “straight pipes” were input directly to corresponding stream reaches.

4.4.2 Livestock

A whole farm approach was used for distribution of manure around each farm, so that all manure produced by a farm was used on the same farm. Approximate farm boundaries were generated by visually aligning contiguous land use parcels from the DCR land use data layer with boundaries from USDA Farm Service Agency (FSA) aerial photographs. Within each farm, four types of land use were considered to be potential locations of livestock manure:

- cropland used for application of stored manure,
- pastures,
- loafing lots or confinement areas, and
- stream access areas in pastures or loafing lots.

Figure 4-2 shows the spatial distribution of these four types of agricultural areas within all farms with inventoried livestock in the downstream portion of the watershed. No other agricultural land received inputs of fecal coliform from livestock manure in the Mountain Run watershed model.

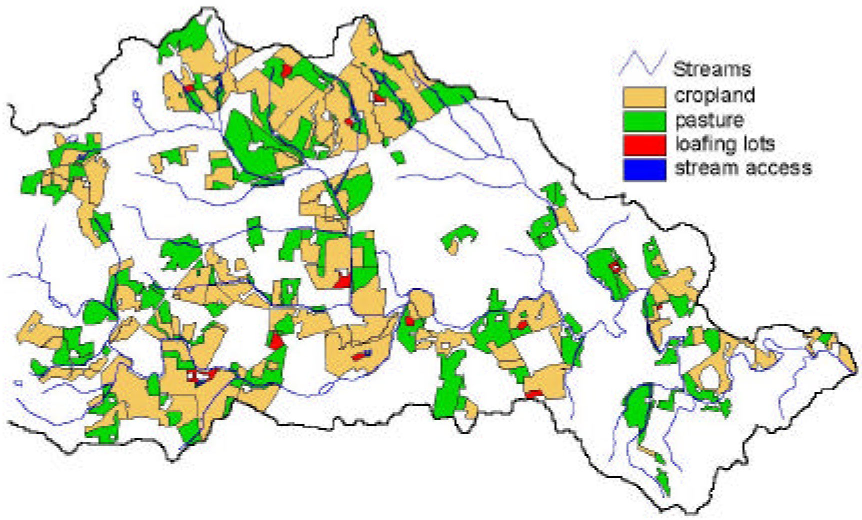

Figure 4-2. Manure-Related Land Types on Livestock Farms Downstream from Culpeper

Seasonal variations in livestock distribution were based upon seasons defined as follows:

- Season 1: Dec-Feb
- Season 2: Mar, Nov
- Season 3: Apr-May, Sep-Oct
- Season 4: Jun-Aug

The following guidelines, quantified in Table 4-2, were used to account for seasonal variations within the various livestock operations:

- If pasture or loafing lots were adjacent to, or included, a perennial stream, livestock access was assumed, unless exclusion had been observed for individual farms. Animals in areas with stream access were assumed to be in the stream a seasonally-variable number of hours per day.
- If confinement or loafing areas were available on a farm with beef or dairy, livestock were considered to be confined a seasonally-variable number of hours per day.
- Beef population was considered to be seasonally variable due to the cyclic nature of cow-calf operations.
- Not all of the four target land types were available on each livestock farm. Livestock numbers, and therefore, manure and fecal coliform loads were distributed among the available land types. Each of these farm areas was in turn sub-divided by sub-watershed, so that fecal coliform loads could be assigned to a specific pervious land segment (PLS).

Table 4-2. Seasonally-Variable Parameters

Animal Type	Season 1 Dec-Feb	Season 2 Mar, Nov	Season 3 Apr-May, Sep-Oct	Season 4 Jun-Aug
stream access (hrs in stream/day)	0	1	2	4
dairy confinement (hrs/day)	24	12	6	4
beef confinement (hrs/day)[1]	24	8	4	0
beef population (% of base)[2]	100	104	106	104

[1]where confinement is available on each farm.
[2]populations of dairy, swine and horses were constant.

For manure storage:

- All manure from dairy, swine and horse confinement areas and 60% of the manure from beef loafing lots was collected and placed in storage for application to cropland areas within the same farm during April and October. The amounts of manure collected in each 6-month period varied, based on the seasonally-variable parameters.
- The one swine operation was totally confined with the exception of 25 head in an open lot. Horses were represented as being stabled 10 hours each day, and on pasture the remainder of the day, year round.
- Fecal coliform in storage was reduced by 97.73%, based on average measurements of fecal coliform in fresh manure and in storage pits.

A computer program was written to distribute fecal coliform from livestock on each farm amongst the four livestock manure application categories, and then from each application category to individual pervious land segments (PLS). The program code is listed in Appendix H for reference. A spreadsheet was then used to format the inputs needed for the monthly loading table. Fecal coliform loads from livestock were calculated in the program using the fecal coliform densities in manure and daily manure production per animal listed in Table 4-3, along with seasonally-variable populations of livestock.

Table 4-3. Data for Livestock Fecal Coliform Calculations

Data Type	Units	beef	dairy	swine	horse
A. daily feces production[1]	grams/AU	18,144	27,216	20,412	18,598
B. fecal coliform density[2]	FC x 10^6/gm	1.143	1.143	3.300	0.0126
C. daily FC production/animal[3]	FC x 10^6/AU	20,740	31,110	67,360	234
D. Season 1 population	AU	3,192	2,073	45	128
E. watershed FC production[4]	FC x 10^{12}/day	66.20	64.49	3.03	0.03

[1] ASAE, 1998. [2] from Table 3-7. [3] calculated as A x B [4] calculated as C x D

Tables 4-4 through 4-7 show the monthly distribution of livestock manure on these various manure-related land types by beef, dairy, swine and horse, respectively.

Table 4-4. Monthly Distribution of Beef Manure (FC x 10^9/day)

Month	PastureFC	LoafLotFC	StreamFC	StorageFC	Cropland
Jan	40,779	6,636	0	9,953	0
Feb	40,779	6,636	0	9,953	0
Mar	48,370	2,180	1,216	3,270	0
Apr	49,239	1,079	2,478	1,618	507
May	49,239	1,079	2,478	1,618	0
Jun	45,791	0	4,675	0	0
Jul	45,791	0	4,675	0	0
Aug	45,791	0	4,675	0	0
Sep	49,239	1,079	2,478	1,618	0
Oct	49,239	1,079	2,478	1,618	70
Nov	48,370	2,180	1,216	3,270	0
Dec	40,779	6,636	0	9,953	0
Total	**553,408**	**28,582**	**26,369**	**42,873**	**577**

Table 4-5. Monthly Distribution of Dairy Manure (FC x 10^9/day)

Month	PastureFC	LoafLotFC	StreamFC	StorageFC	Cropland
Jan	5,609	5,459	0	21,838	0
Feb	5,609	5,459	0	21,838	0
Mar	21,538	3,190	770	12,760	0
Apr	26,250	1,467	1,540	5,867	2,304
May	26,250	1,467	1,540	5,867	0
Jun	27,863	1,012	3,081	4,048	0
Jul	27,863	1,012	3,081	4,048	0
Aug	27,863	1,012	3,081	4,048	0
Sep	26,250	1,467	1,540	5,867	0
Oct	26,250	1,467	1,540	5,867	677
Nov	21,538	3,190	770	12,760	0
Dec	5,609	5,459	0	21,838	0
Total	**248,492**	**31,661**	**16,944**	**126,644**	**2,981**

Table 4-6. Monthly Distribution of Swine Manure (FC x 10^9/day)

Month	PastureFC	LoafLotFC	StreamFC	StorageFC	Cropland
Jan	337	135	0	2,560	0
Feb	337	135	0	2,560	0
Mar	586	234	0	4,452	0
Apr	337	135	0	2,560	349
May	337	135	0	2,560	0
Jun	586	234	0	4,452	0
Jul	586	234	0	4,452	0
Aug	586	234	0	4,452	0
Sep	337	135	0	2,560	0
Oct	337	135	0	2,560	349
Nov	586	234	0	4,452	0
Dec	337	135	0	2,560	0
Total	**5,287**	**2,114**	**0**	**40,179**	**697**

Table 4-7. Monthly Distribution of Horse Manure (FC x 10^9/day)

Month	PastureFC	LoafLotFC	StreamFC	StorageFC	Cropland
Jan	20	0	0	10	0
Feb	20	0	0	10	0
Mar	21	0	0	11	0
Apr	19	0	1	10	1
May	19	0	1	10	0
Jun	20	0	1	11	0
Jul	20	0	1	11	0
Aug	20	0	1	11	0
Sep	19	0	1	10	0
Oct	19	0	1	10	1
Nov	21	0	0	11	0
Dec	20	0	0	10	0
Total	**237**	**0**	**7**	**124**	**2**

4.4.3 Wildlife

Literature and measured values of fecal coliform density and daily feces production rates were used along with the distributed wildlife populations to calculate fecal coliform loads from wildlife in each PLS area. Table 4-8 shows the values and sources of information for these calculations, and Table 4-9 shows the distribution of wildlife among the various sub-watersheds. Observations in the watershed indicated that, near streams, wildlife scat was plentiful, but was generally deposited on rocks and horizontal tree trunks. Contributions from wildlife, therefore, were modeled as surface loads subject to washoff during storms, and not as a direct nonpoint load to the stream.

Table 4-8. Data for Wildlife Fecal Coliform Calculations

Data Type	Units	deer	duck	geese	muskrat	raccoon
A. daily feces production[1]	grams/animal	772	299	163	100	450
B. fecal coliform density[2]	FC x 10^6/gm	0.45	16.23	0.8	0.25	0.25
C. daily FC production/animal[3]	FC x 10^6/head	347	4,853	130	25	113
D. summer population	number	1,469	223	500	1,289	1,175
E. watershed total[4]	FC x 10^{12}/day	0.51	1.08	0.06	0.03	0.13

[1] Daily Feces Production Sources

- deer: (772) calculated from the indigestible fraction of daily forage intake, averaged for summer and winter – Halls, 1984.

season	body weight (kg)		forage intake (gm/kg)		indigestible fraction		seasonal average
summer	53.5	x	30	x	0.53	=	850.65
winter	48.5	x	28	x	0.51	=	692.58
					overall average	=	772

- duck: (299) – 110# manure/1000# x 6#/duck x 453.6 gm/# = 299 gm/duck (ASAE, 1998).
- goose: (163) calculated from the average daily FC production of ~10^7 cfu/head/day divided by the average of a range of FC densities (0.0316 – 1.00 x 10^6 cfu/gram) cited in Weiskel et al., 1996.
- muskrat: (100) Kator and Rhodes, 1996.
- raccoon: (450) personal communication with Pat Scanlon (similar to dog).
  Dog estimate (450 gm): Weiskel et al., 1996.

[2] Fecal Coliform Density Sources

- deer, raccoon, muskrat, and goose: Table 3-7.
- duck: (16.23) calculated as 81x10^{10} FC/110 lbs manure x 1 lb/453.6 gm = 16.23 x 10^6 FC/gm (ASAE, 1998).

[3] Daily FC Production/animal was calculated by multiplying lines A and B.

[4] Calculated as C x D

Table 4-9. Distribution of Wildlife by Sub-watershed

Sub-watershed	Deer	Duck	Goose	Muskrat	Raccoon
1	12	4	7	22	14
2	224	58	55	298	172
3	61	19	5	95	50
4	126	21	61	152	141
5	34	1	30	0	47
6	187	19	64	99	147
7	37	1	19	10	27
8	41	2	16	0	16
9	24	0	30	0	17
10	216	20	72	191	190
11	142	10	71	51	143
12	235	46	44	250	143
13	23	14	0	59	30
14	108	9	11	63	34
15	1	0	14	0	3
16	0	0	0	0	0
Total	**1,469**	**223**	**500**	**1,289**	**1,175**

The populations of ducks and geese were varied seasonally to account for an influx of migrating geese over the winter and for increases in wood duck population through its annual reproduction cycle (Lovelace, 1999), as shown in Table 4-10.

Table 4-10. Multiplication Factors for Monthly Waterfowl Distribution

Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ducks	2	2	1	1	1	1	1	1	1	1.3	1.6	2
geese	2	2	1	1	1	1	1	1	1	1	1	2

4.4.4 Urban Stormwater Runoff

Urban and developing areas were modeled as being 60% pervious and 40% impervious. Both pervious and impervious areas were modeled using a buildup/washoff procedure. Daily loading rates of fecal coliform to the impervious areas were arrived at through calibration, with the loading rate on the pervious component estimated as half that of the impervious component.

4.5 Existing FC Loading to Pervious Areas

Within each sub-watershed, fecal coliform loading from each source was associated with different pervious land uses. For each source, this loading was apportioned among the various associated land uses in each sub-watershed and converted to unit-area loadings for input to the model. Livestock manure was distributed to three different land uses and also as a direct nonpoint source. Land uses associated with livestock loading were pasture, loafing lots, and cropland receiving spread manure; direct deposition from livestock with stream access, a direct nonpoint source, was defined as a fourth application category. Four seasonal sets of data were generated with a computer program to account for seasonally-variable conditions for livestock. Loading data for livestock – beef, dairy, swine, and horse; for wildlife – deer, raccoon, muskrat, goose, and duck; for suspected septic system failures; and for the pervious component of urban/developing areas – were each assembled in an individual PLS / month matrix, and then all were summed together and divided by the acreage in each PLS for the final daily fecal coliform loading rate table. Daily fecal coliform loading rates for existing conditions are summarized by sub-watershed in Table 4-11.

Table 4-11. Monthly FC Loading to Pervious Areas by Sub-watershed (FC/ac-day * 10^6)

WS	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
1	2,191	2,191	2,201	2,241	2,241	2,121	2,121	2,121	2,241	2,262	2,241	2,191	2,197
2	1,167	1,167	1,124	1,214	1,120	1,023	1,023	1,023	1,120	1,212	1,159	1,167	1,126
3	1,273	1,273	1,792	1,900	1,900	1,790	1,790	1,790	1,900	1,920	1,832	1,273	1,703
4	1,063	1,063	1,183	1,219	1,198	1,094	1,094	1,094	1,198	1,209	1,200	1,063	1,140
5	1,312	1,312	2,279	2,872	2,692	2,594	2,594	2,594	2,692	2,738	2,281	1,312	2,272
6	3,808	3,808	4,002	4,113	4,064	3,757	3,757	3,757	4,064	4,083	4,014	3,808	3,920
7	1,992	1,992	4,009	5,020	4,756	4,574	4,574	4,574	4,756	4,830	4,010	1,992	3,923
8	1,398	1,398	1,385	1,385	1,385	1,385	1,385	1,385	1,385	1,389	1,392	1,398	1,389
9	3,436	3,436	3,433	3,433	3,433	3,433	3,433	3,433	3,433	3,433	3,433	3,436	3,433
10	3,275	3,275	3,654	3,879	3,811	3,628	3,628	3,628	3,811	3,836	3,663	3,275	3,613
11	847	847	1,923	2,637	2,413	2,490	2,490	2,490	2,413	2,479	1,929	847	1,984
12	1,513	1,513	1,747	1,991	1,897	1,819	1,819	1,819	1,897	1,935	1,774	1,513	1,770
13	306	306	166	166	166	166	166	166	166	208	250	306	212
14	2,618	2,618	2,606	2,596	2,596	2,511	2,511	2,511	2,596	2,601	2,616	2,618	2,583
15	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**26,198**	**26,198**	**31,504**	**34,666**	**33,671**	**32,384**	**32,384**	**32,384**	**33,671**	**34,134**	**31,795**	**26,198**	

4.6 Modeling the Future Land Use Scenario

A future land use plan was developed jointly by the Town and the County of Culpeper in 1994. Future land use change within the watershed was estimated from population growth information in Table 4-12.

Table 4-12. Future Growth Projections

	Population		Population Increases			Land Use Change	
County Area	1990	Projected 2000	10-yr % Increase	Population[1]	No. of Families[2]	Acreage / Fam. Unit	Increased Acreage
Town	8,581	12,100	41%	4,961	1,240	0.25	310
Within 2 miles	4,025	5,400	34.2%	1,847	462	0.25	115
County	27,791	33,210	19.5%	3,238	810	2.5	2025

[1] Based on half of the growth in the county, outside of the Town of Culpeper, taking place within Mountain Run watershed.

[2] Based on 4 people per family unit.

Using this assessment of growth, the overall watershed acreage in the "urban/developing category" would increase by 425 acres, and the "rural residential" category by 2,025 acres. A map developed as part of the Culpeper 21 Plan outlines designated areas of future growth for rural residential, low- and medium-density housing, commercial and industrial categories of land use. For purposes of this TMDL analysis, low- and medium-density housing, commercial and industrial land uses were all considered to be in the "urban/developing" category.

The acreages for "rural residential" and the combined "urban/developing" categories were summarized by modeling sub-watershed. The acreage increases for both categories were assigned to sub-watershed by the proportionate extent of each category in each sub-watershed. Within each sub-watershed, these increases were offset by equal decreases in acreage from forest (-10%), cropland (-30%), and from pasture (-60%).

Per acre fecal coliform loadings remained the same for each land use category. Changes were effected by the relative shifts in acreages within each land use category for each sub-watershed. Reductions in livestock were simulated by reducing fecal coliform loadings from "cows in stream" in proportion to the percentage decrease in pastureland within each sub-watershed.

For future conditions, loading from each permitted point source will be simulated as its permitted maximum daily flow times its permitted daily mean fecal coliform concentration, as shown in Table 4-13.

Table 4-13. Permitted Dischargers of Fecal Coliform in Mountain Run

Discharger	Permitted Flow		Permitted [FC] (cfu/100 mL)	WLA (cfu/day)
	Volume (MGD)	Rate (cfs)		
Mt. Dumplin STP	0.3	0.46416	200	2.27118×10^{9}
Ferguson STP	0.0025	0.00387	200	1.89265×10^{7}
Mountain Run STP	0.3	0.46416	200	2.27118×10^{9}
Town of Culpeper WWTP	3.0	4.64160	200	2.27118×10^{10}
å **WLA**				$\mathbf{2.72731 \times 10^{10}}$

4.7 Model Calibration Process

Model calibration is the process of adjusting select parameter values in order to make simulated output comparable to observed measurements for key components in the model. The three types of parameters calibrated for the Mountain Run watershed model related to daily flows (hydrology), fecal coliform concentrations (water quality) from urban areas, and fecal coliform concentrations (water quality) from all sources.

4.7.1 Hydrologic Parameter Calibration

The 1986-1989 period of rainfall was chosen for the calibration model runs, since it was representative of a wide variety of rainfall conditions, including contiguous years of wet, dry and normal annual rainfall, and was a relatively complete period of record from the Culpeper station. The watershed upstream from the USGS flow gaging station was used to calibrate the hydrologic parameters in the model. A number of sub-watersheds were defined within this calibration watershed, and channel cross-sections were estimated at the mouth of each sub-watershed from site visits. The calibration watershed, shown in Figure 4-3 with its defined reaches and sub-watersheds, includes Mountain Run Lake, which was modeled as a reservoir. Stage-discharge curves for outflow were obtained from USDA-NRCS in Richmond and used to simulate storage and outflow from the reservoir reach. Hydrologic parameter values calibrated for this site were then applied to the downstream model of Mountain Run watershed.

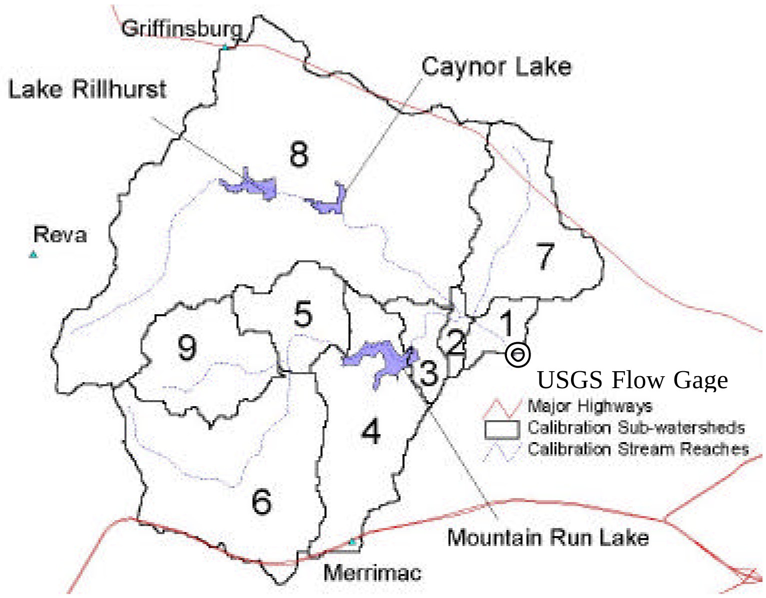

Figure 4-3. Calibration Watershed: Sub-watersheds and Stream Reaches

The hydrologic calibration was performed with advice provided by USGS's HSPEXP program (Lumb et al., 1994) for analyzing calibration parameters. The advice is based on a comparison of observed flow with modeled flow for a set of representative storms from the calibration period. Thirty-two storms were selected from the 1/1/1986 to 12/31/1989 calibration period. The hydrologic calibration was performed using a combination of visual assessment of "fit" between the observed and simulated data, and trial-and-error interpretation of the guidance provided by HSPEXP.

During the calibration period, several mismatches were noted between rainfall conditions or the reported rainfall at the rain gauge, and runoff conditions or reported flow at the flow station. Several storms were modeled with higher peaks than observed, probably because the top half of the watershed was not modeled as having the storage provided by two smaller impoundments, Caynor Lake and Lake Rillhurst. Inclusion of the impoundments would most likely dampen the peaks of the larger storms. The calibration criteria used by HSPEXP and the statistics for the calibration are shown in Table 4-14. Calibration was continued until as many of the criteria could be met as possible, without sacrificing the visual "fit" of the majority of the storms. Figure 4-4 shows a comparison between the calibrated and observed flow for 1988, and Figure 4-5 shows a comparison between simulated and observed 30-day geometric mean flow over the entire calibration period. The simulated flow generally follows the trends in observed runoff and base flow and produces peaks and low flow volumes comparable to the observed flow.

Table 4-14. HSPF Hydrologic Calibration Criteria and Statistics

	Simulated	Observed
Total annual runoff, in inches	48.340	52.069
Total of highest 10% flows, in inches	21.110	24.386
Total of lowest 50% flows, in inches	8.720	8.296
Total storm volume, in inches	23.320	24.316
Average of storm peaks, in cfs	95.832	94.563
Baseflow recession rate	0.960	0.930
Summer flow volume, in inches	7.790	9.060
Winter flow volume, in inches	11.740	12.633
Summer storm volume, in inches	3.120	2.614
	Current	Criteria
Error in total volume	-7.200	10.000
Error in low flow recession	-0.030	0.010
Error in 50% lowest flows	5.100	10.000
Error in 10% highest flows	-13.400	15.000
Error in storm volumes	1.300	15.000
Seasonal volume error	6.900	10.000
Summer storm volume error	23.500	15.000

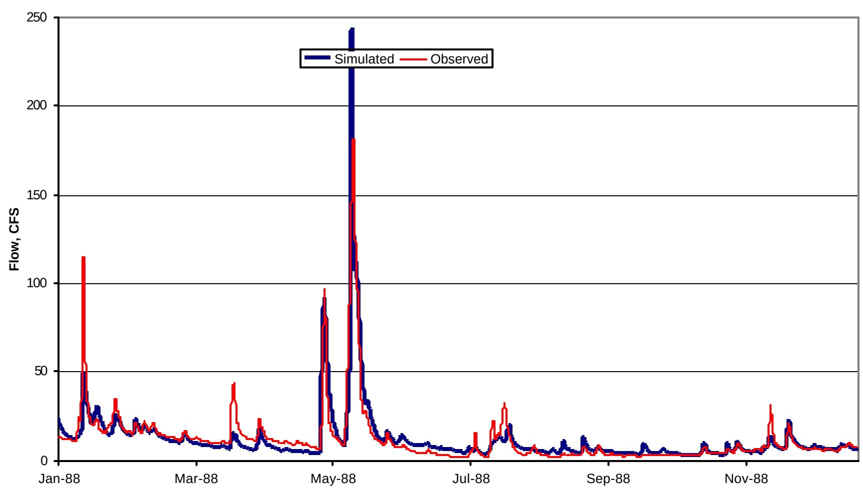

Figure 4-4. Hydrology Calibration: Simulated and Observed Daily Flow, 1988

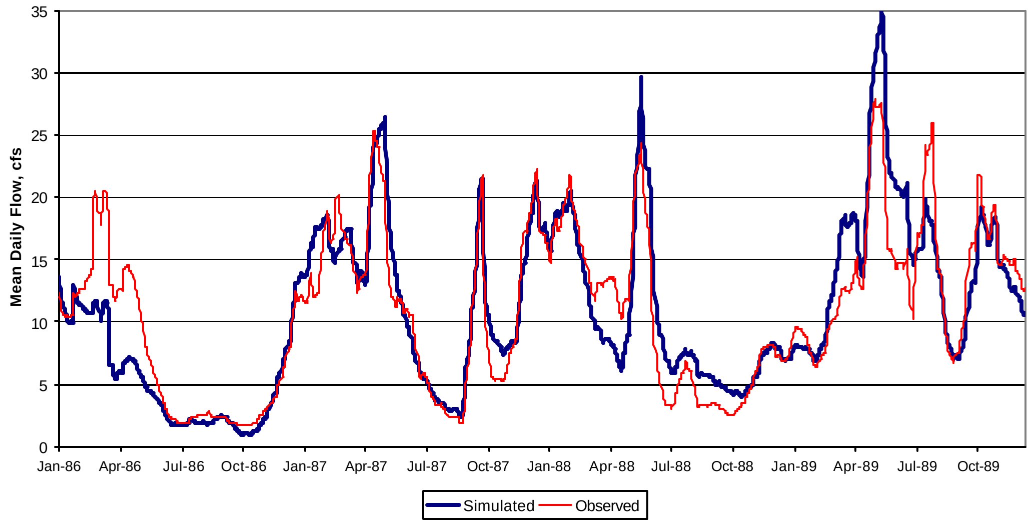

Figure 4-5. Hydrology Calibration: Simulated and Observed 30-Day Geometric Mean Flow, 86-89

4.7.2 Hydrologic Component Validation

Validation ensures that the calibrated parameters are appropriate for time periods other than the calibration period. In order to assess the applicability of these calibrated parameters for other climatic conditions, the model was run using climatological inputs for the 1982-1985 time period. Figure 4-6 shows a visual comparison between simulated and observed for a single year within that period, 1983, to show more detail. The calibrated model performed well with the second data seta and should adequately represent conditions in Mountain Run.

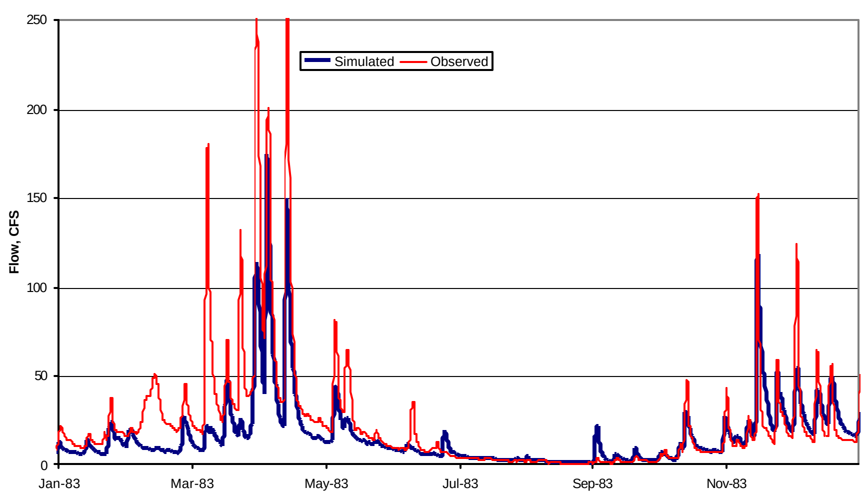

Figure 4-6. Hydrology Validation: Simulated and Observed Daily Flow, 1983

A further check was made to verify that the calibrated model was appropriately simulating the various flow components. Output from the model was compared with output from HYSEP, a USGS program for estimating the percentage of base flow from long-term daily flow records at its various gaging stations.

The Mountain Run model was run with a 21-month period of record and configured to generate daily total volumes of runoff from four different sources – pervious runoff, impervious runoff, interflow, and baseflow. These four sources were added for total flow. Baseflow was calculated as a percentage of total flow and compared with the percentage calculated from the USGS program. HYSEP was used to analyze an 18-yr period of record from the USGS station on Mountain Run used for hydrologic calibration. The percentage of modeled baseflow was 50.9% of total flow, while the HYSEP program estimated baseflow as 56.4% of total flow. These comparable results further confirm that the hydrologic calibration has been performed in a reasonable manner.

4.7.3 Urban Runoff Fecal Coliform Calibration

The calibrated hydrologic parameter values were added to the Mountain Run watershed model prior to calibrating the fecal coliform parameters for urban areas. The period between January 1, 1996 and September 30, 1997 was chosen for calibration of urban in-stream fecal coliform concentrations, because observed fecal coliform concentrations, [FC], were available from both DEQ and RRPDC during this period. Although additional samples were collected after this date by both agencies, flow recording at the upstream USGS gaging station was discontinued on October 2, 1997. Since flow from this station was being used in lieu of modeling the upper portion of the watershed, modeling past this point in time was not possible.

Urban water quality (fecal coliform) parameters were calibrated at the exit from Reach 9. The sub-watershed containing this reach includes the majority of the Town of Culpeper, with all upstream inputs of fecal coliform blocked by Lake Pelham. Therefore monitored in-stream fecal coliform in this reach were attributed solely to urban sources. Calibration of the fecal coliform parameters for impervious areas was guided by research reported for small urban communities that indicated approximately constant surface unit-area loads of fecal coliform at any given location, washoff proportional to runoff (Mallard, 1980), and in-stream concentrations independent of days since the last runoff (Olivieri et al., 1977). Fecal coliform loading on the impervious area was calibrated as 2.0 x 109 cfu/ac-day, with a maximum buildup between runoff events of twice that amount, and the amount of rainfall needed to remove 90% of the built-up load as 0.5 in/day. For impervious areas, these values are consistent with our understanding of the buildup/washoff process – a fairly quick establishment of equilibrium between loading and die-off, and more frequent loading from smaller storms compared to pervious areas.

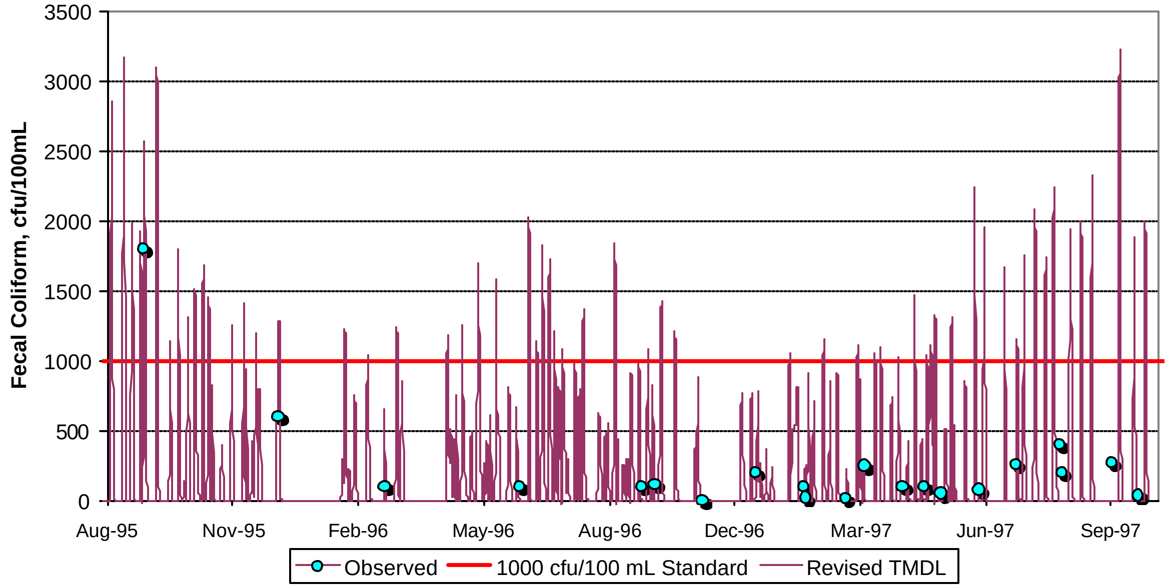

Figure 4-7. Urban FC Calibration: Simulated and Observed Concentrations, Reach 9

Figure 4-7 shows the continuous simulated daily average [FC] throughout the calibration period along with the observed instantaneous [FC] measurements. Most of the observed concentrations were reported during baseflow conditions, where lower values were observed. Runoff events are expected to produce higher values, but were not explicitly captured with the observed points in the Figure 4-7. Values as high as 3,500 cfu/100 mL have been reported at this site by DEQ between 1987 and 1995, while concentrations of 4,400 and 5,900 cfu/100 mL were reported for a July 1999 storm and concentrations from three samples exceeding the analysis threshold of 8,000 cfu/100 mL were reported for a June 2000 storm by the Culpeper SWCD. The range of simulated urban concentrations was calibrated to extend to the lower end of this range of observed storm concentrations from different time periods.

4.7.4 Overall Fecal Coliform Parameter Calibration

After calibrating the urban fecal coliform concentrations in Reach 9, a separate calibration was performed at the watershed outlet, where a combined set of observed [FC] concentrations was available from DEQ and RRPDC. Since all sources in the watershed can contribute at this point and the urban parameters were already calibrated, only non-urban parameters were adjusted for this calibration. The overall fecal coliform calibration was achieved through the adjustment of four parameters: FSTDEC - the first order decay rate coefficient, TWAT - mean monthly water temperature, WSQOP – the amount of rainfall necessary to remove 90% of accumulated load, and the amount of available fecal coliform in direct deposition of livestock manure in streams. TWAT was changed from a single constant value to a monthly mean (calculated as the long-term mean monthly air temperature) in order to better match seasonal trends apparent in the simulated geometric means. A value of 5% of calculated in-stream livestock deposits was used to represent the amount of fecal coliform that was available for transport in stream flow. While this may seem like a low figure, it is supported with research by Gifford and Kress (1984) which showed that for baseflow conditions, 95% of the fecal coliform from a slurry of livestock manure introduced to a stream disappeared, or became unavailable, within 50 meters.

Figure 4-8 shows the comparison between observed and simulated fecal coliform concentrations. The two large observed values could not be matched. These observations were taken on days without rainfall and may represent sampling error. The calibration was used to simulate as broad a range of observed values as possible, while maintaining a close correspondence during base flow.

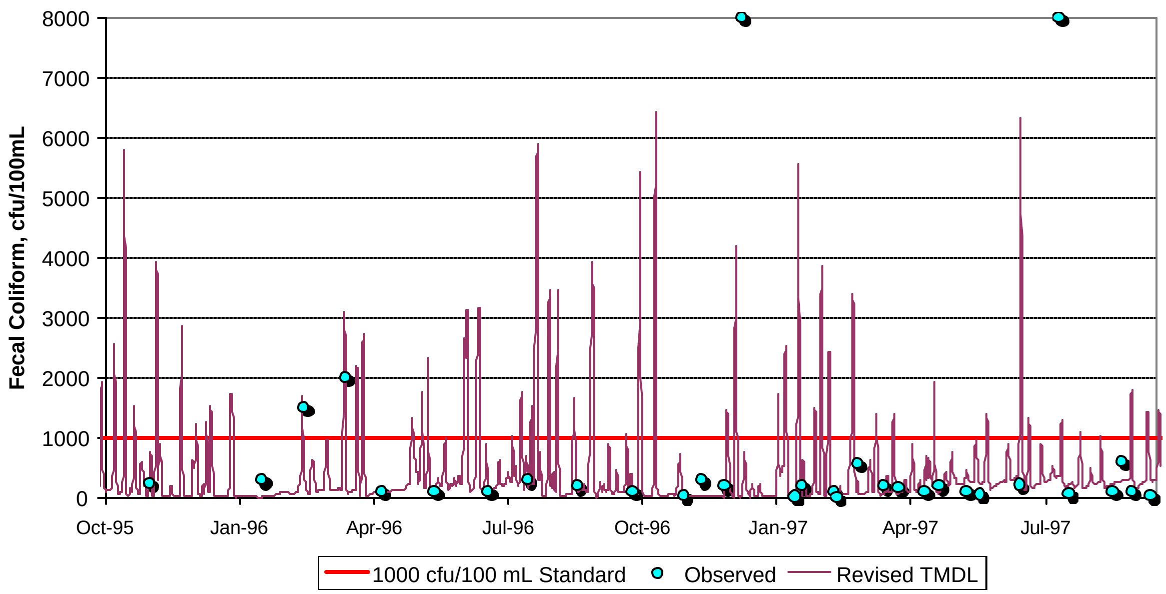

Figure 4-8. Overall FC Calibration: Simulated and Observed Concentrations, Watershed Outlet

4.7.5 Representation of Die-Off in the Model

Die-off in storage was incorporated in the Fortran program used to distribute livestock fecal coliform loading to pervious land segments. An in-storage die-off percentage of 97.73% was calculated from a series of measurements of fecal coliform in fresh manure and in stored manure during land application.

Die-off from the pervious portions of the watershed was modeled with HSPF's first-order decay function. For all general quality constituents, the REMQOP factor is approximately equal to the first order decay coefficient, k, in Chick's Law. Chick's Law is generally written as follows:

$$N_t = N_0 * e^{(-k*t)}$$

where N_t and N_o are the final and initial sample concentrations, respectively, and t is the time in between samples. REMQOP was calculated as 0.11 from research by Thelin and Gifford (1985). Since REMQOP = ACQOP/SQOLIM, SQOLIM can be expressed as a multiple of ACQOP (MF x ACQOP). For k=0.11, this equals a MF = 9, which was the value used in the Mountain Run model.

Impervious portions of the watershed also used the first order decay function. In research conducted by Olivieri et al. (1977), bacteria concentrations in runoff appeared to be independent of the days since the last rainfall event, indicating either a very rapid buildup or an accumulation limit (maximum loading) not much greater than daily loading. A lower multiplication factor was indicated by this reasoning, and a MF = 2 was arrived at through calibration.

In-stream die-off was also included in the model for which FSTDEC was set equal to 1.0. Table 4-15 includes a listing of the various input parameters used in HSPF simulations for Mountain Run.

Table 4-15. Input Parameters used in HSPF Simulation for Mountain Run

			RANGE OF VALVES					
PARAMETER	DEFINITION	UNITS	TYPICAL		POSSIBLE		FINAL	FUNCTION OF…
PERLND Parameters			MIN	MAX	MIN	MAX	CALIB.	
PWAT-PARM2								
FOREST	Fraction forest cover	none	0.00	0.5	0	0.95	1.0 forest, 0.0 other	Forest cover
LZSN	Lower zone nominal soil moisture storage	inches	3	8	2	15	6.0	Soil properties*
INFILT	Index to infiltration capacity	in/hr	0.01	0.25	0.001	0.5	0.024-0.200[1]	Soil and cover conditions
LSUR	Length of overland flow	feet	200	500	100	700	40.3-873.0[1]	Topography
SLSUR	Slope of overland flowplane	none	0.01	0.15	0.001	0.3	0.024-0.173[1]	Topography
KVARY	Groundwater recession variable	1/in	0	3	0	5	0	Calibrate*
AGWRC	Base groundwater recession	none	0.92	0.99	0.85	0.999	0.975-0.99[2]	Calibrate*
PWAT-PARM3								
PETMAX	Temp below which ET is reduced	deg. F	35	45	32	48	40	Climate, vegetation
PETMIN	Temp below which ET is set to zero	deg. F	30	35	30	40	35	Climate, vegetation
INFEXP	Exponent in infiltration equation	none	2	2	1	3	2	Soil properties
INFILD	Ratio of max/mean infiltration capacities	none	2	2	1	3	2	Soil properties
DEEPFR	Fraction of GW inflow to deep recharge	none	0	0.2	0	0.5	0.3	Geology*
BASETP	Fraction of remaining ET from baseflow	none	0	0.05	0	0.2	0.03	Riparian vegetation*
AGWETP	Fraction of remaining ET from active GW	none	0	0.05	0	0.2	0	Marsh/wetlands ET*
PWAT-PARM4								
CEPSC	Interception storage capacity	inches	0.03	0.2	0.01	0.4	monthly[2]	Vegetation
UZSN	Upper zone nominal soil moisture storage	inches	0.10	1	0.05	2	0.95	Soil properties
NSUR	Mannings' n (roughness)	none	0.15	0.35	0.1	0.5	0.10-0.40[2]	Land use, surface condition
INTFW	Interflow/surface runoff partition parameter	none	1	3	1	10	1.5	Soils, topography, land use
IRC	Interflow recession parameter	none	0.5	0.7	0.3	0.85	0.6	Soils, topography, land use
LZETP	Lower zone ET parameter	none	0.2	0.7	0.1	0.9	monthly[2]	Vegetation
QUAL-INPUT								
ACQOP	Rate of accumulation of constituent	#/day					monthly[2]	Land use
SQOLIM	Maximum accumulation of constituent	#					9 x ACQOP	Land use
WSQOP	Wash-off rate	in/hr					1.8	Land use
IOQC	Constituent conc. in interflow	$\#/ft^3$					0	Land use
AOQC	Constituent conc. in active groundwater	$\#/ft^3$					0	Land use

[1] Varies by individual PERLND [2] Varies with land use

Table 4-16 (Cont). Input Parameters used in HSPF Simulation for Mountain Run

			RANGE OF VALVES					
PARAMETER	DEFINITION	UNITS	TYPICAL		POSSIBLE		FINAL	FUNCTION OF…
			MIN	MAX	MIN	MAX	CALIB.	
IMPLND Parameters								
IWAT-PARM2								
LSUR	Length of overland flow	feet	200	500	100	700	90.6-696.9[1]	Topography
SLSUR	Slope of overland flowplane	none	0.01	0.15	0.001	0.3	0.036-0.101[1]	Topography
NSUR	Mannings' n (roughness)	none	0.15	0.35	0.1	0.5	0.1	Land use, surface condition
RETSC	Retention/interception storage capacity	inches	0.03	0.2	0.01	0.4	0.065	Land use, surface condition
IWAT-PARM3								
PETMAX	Temp below which ET is reduced	deg. F	35	45	32	48	40	Climate, vegetation
PETMIN	Temp below which ET is set to zero	deg. F	30	35	30	40	35	Climate, vegetation
IQUAL								
ACQOP	Rate of accumulation of constituent	#/day					2.00E+09	Land use
SQOLIM	Maximum accumulation of constituent	#					2 x ACQOP	Land use
WSQOP	Wash-off rate	in/hr					0.5	Land use
RCHRES Parameters								
HYDR-PARM2								
KS	Weighting factor for hydraulic routing						0.0	
GQUAL								
FSTDEC	First order decay rate of the constituent	1/day					1.0	
THFST	Temperature correction coeff. for FSTDEC						1.05	

[1] Varies by individual PERLND

5.0 TMDL ALLOCATION

5.1 Overview

The objective of a TMDL plan is to allocate allowable loads among different pollutant sources so that the appropriate control actions can be taken to achieve water quality standards (USEPA, 1991). The objective of the TMDL plan for Mountain Run was to determine what reductions in fecal coliform loadings from point and nonpoint sources are required to meet state water quality standards. The state water quality standard for fecal coliform used in the development of the TMDL was 200 cfu/100mL (30-day geometric mean). The TMDL considers all sources contributing fecal coliform to Mountain Run. The sources can be separated into nonpoint and point (or direct) sources. The incorporation of the different sources into the TMDL are defined in the following equation:

$$TMDL = W\ L\ A + L\ A + MOS$$

where,

WLA	=	waste load allocation (point source contributions);
LA	=	load allocation (nonpoint source contributions); and
MOS	=	margin of safety.

5.2 Margin of Safety

A margin of safety (MOS) is included to account for any uncertainty in the TMDL development process. There are several different ways that the MOS could be incorporated into the TMDL (EPA, 1991). For the Mountain Run TMDL, a MOS of 5% was incorporated explicitly in the TMDL equation, in effect reducing the target TMDL from the state water quality standard for fecal coliform – a 30-day geometric mean concentration of 200 cfu/100mL – to 190 cfu/100mL.

5.3 Waste Load Allocation

All VPDES-permitted point source discharges with allowable [FC] were added to the model. Of these, only the Culpeper WWTP is currently on line. The Culpeper WWTP currently applies tertiary treatment to its waste discharge, and produces essentially fecal coliform-free discharge. For the existing loading condition, the Culpeper WWTP daily discharge was used together with its reported concentration of 0 cfu/100 mL. All of these permitted facilities have both permitted monthly-averaged daily flow rates and a permitted discharge limit for fecal coliform of 200 cfu/100 mL. Under the future scenario and all TMDL reduction scenarios, this reserved fecal coliform loading was incorporated for each facility as their maximum permitted daily flow rate times the permitted fecal coliform concentration. The annual load contributed by each facility is given in Table 5-1.

Table 5-1. Annual Fecal Coliform WLA

Permitted Discharge Facility	Annual Fecal Coliform Load (cfu/yr)
Mt. Dumplin STP	8.290×10^{11}
Ferguson STP	6.908×10^{9}
Mountain Run STP	8.290×10^{11}
Town of Culpeper WWTP	8.290×10^{12}
å **WLA (Load to Stream)**	$\mathbf{9.955 \times 10^{12}}$

5.4 Load Allocation

The existing fecal coliform loading from the Mountain Run watershed is attributed solely to non-point sources as detailed previously (including direct nonpoint sources such as “straight pipes” and direct deposition by livestock in streams). Reductions in fecal coliform loading will be required from some combination of these sources in order to meet the designated TMDL. The existing fecal coliform concentrations and loadings were first defined and separated by source and sub-watershed to assist in the analysis. Dominant fecal coliform sources identified in the analysis were then subjected to five different allocation/reduction schemes for meeting the TMDL target, using future conditions as the base against which reductions were made.

5.5 Existing Conditions

After all of the hydrology and fecal coliform parameters were calibrated and incorporated into the model, the model was run under existing conditions of land use and fecal coliform loading.

Table 5-2 shows the total annual fecal coliform load applied to the pervious and impervious areas of the watershed, averaged over the 4-year simulation period. Table 5-3 shows the total annual fecal coliform load delivered to the edge-of-stream from both the land-based sources and the direct nonpoint sources which contribute directly to the stream. The last line in Table 5-3 shows the amount of load delivered to the outlet from each source. The resulting in-stream concentrations at the outlet from all sources combined are illustrated in Figures 5-2 and 5-3 for daily average fecal coliform concentrations, and 30-

day geometric mean concentrations, respectively. The 30-day geometric mean TMDL target of 190 cfu/100 mL is exceeded 59% of the time over the 4-year simulation period for existing conditions.

Table 5-2. Existing Conditions: Annual Fecal Coliform Loads Applied to the Land

(cfu * 10^{10}/yr)

Sub-Watershed	Livestock	Wildlife	Septic	Urban Pervious	Urban Buildup	Total
1	19,431	1,099	86	0	0	20,615
2	181,989	17,833	65	0	0	199,887
3	78,910	5,488	55	0	0	84,453
4	119,487	7,587	427	2,187	2,916	132,603
5	96,216	980	370	2,310	3,080	102,957
6	641,829	7,947	695	2,992	3,989	657,452
7	176,660	847	80	58	77	177,721
8	7	1,122	0	5,255	7,006	13,390
9	0	623	0	27,576	36,768	64,967
10	738,011	8,847	574	6,727	8,969	763,129
11	274,538	5,102	1,503	2,505	3,340	286,988
12	297,431	14,780	17	937	1,249	314,413
13	0	3,649	0	0	0	3,649
14	68,949	3,789	290	22,637	30,182	125,847
15	0	0	0	0	0	0
16	0	0	0	0	0	0
Total	**2,693,457**	**79,692**	**4,161**	**73,183**	**97,577**	**2,948,070**

Table 5-3. Existing Conditions: Annual FC Loads Delivered to the Edge-of-Stream

(cfu * 10^{10}/yr)

Reach	Livestock	Wildlife	Septic	Urban Pervious	Straight Pipes	Cows-in-streams	Urban Washoff	Total
1	366	19	2	0	0	0	0	386
2	6,586	339	1	0	175	314	0	7,415
3	1,590	148	2	0	6	435	0	2,181
4	3,359	127	6	143	7	544	668	4,855
5	2,874	33	13	179	460	622	706	4,886
6	18,585	150	11	159	34	1,528	912	21,380
7	4,229	23	2	4	21	462	18	4,759
8	0	15	0	125	1	0	1,604	1,745
9	0	9	0	575	1	0	8,409	8,994
10	25,668	182	14	153	69	1,750	2,049	29,885
11	13,218	212	56	143	272	498	764	15,164
12	6,778	220	0	85	149	451	287	7,970
13	0	45	0	0	53	0	0	98
14	1,375	67	7	649	760	59	6,905	9,822
15	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0
Reach Total In	**84,628**	**1,589**	**114**	**2,214**	**2,009**	**6,663**	**22,323**	**119,541**
Reach Total Out	**60,774**	**1,241**	**83**	**1,484**	**1,109**	**3,201**	**12,207**	**80,099**

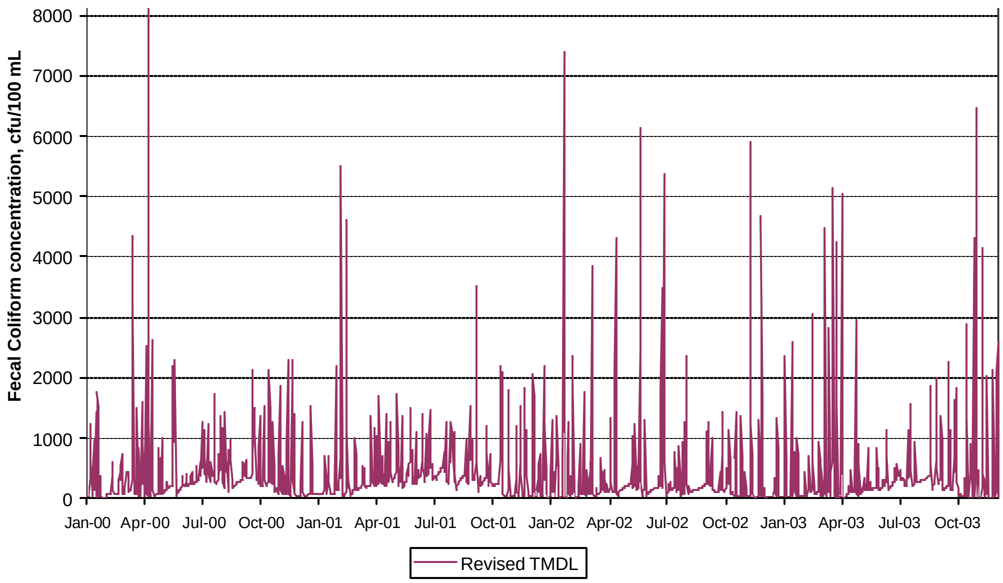

Figure 5-1. Existing Conditions: Simulated Daily FC Concentrations

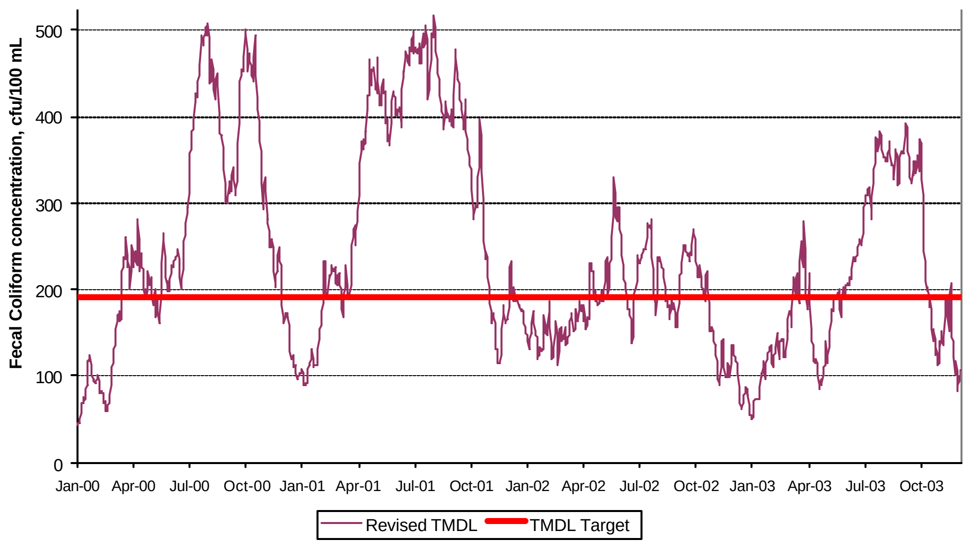

Figure 5-2. Existing Conditions: 30-Day Geometric Mean FC Concentrations

5.6 Alternative Allocation Scenarios

All of the alternative scenarios developed to meet the target TMDL for Mountain Run were based on projected future conditions. In the future conditions scenario, all permitted fecal coliform discharges were included in the loading at their maximum levels, in accordance with state regulations. Additionally, since “straight pipes” and faulty septic systems are already covered by existing regulations, loads from these sources are totally removed in all TMDL scenarios. Table 5-4 shows the total annual fecal coliform load applied to the pervious and impervious areas of the watershed, averaged over the 4-year simulation period. Table 5-5 shows the total annual fecal coliform load delivered to the edge-of-stream from the land-based, the direct nonpoint, and the permitted sources that contribute directly to the stream. The last line in Table 5-5 shows the amount of load delivered to the outlet from each source. The resulting in-stream concentrations at the outlet from all sources are illustrated in Figures 5-3 as 30-day geometric means. The 30-day geometric mean TMDL target of 190 cfu/100 mL is exceeded 59% of the time over the 4-year simulation period for these base future conditions.

Table 5-4. Future Conditions: Annual Fecal Coliform Loads Applied to the Land

(cfu * 10^{10}/yr)

Sub-Watershed	Livestock	Wildlife	Septic	Urban Pervious	Urban Buildup	Total
1	19,431	1,099	86	0	0	20,615
2	180,678	17,833	65	0	0	198,576
3	70,312	5,488	55	0	0	75,855
4	88,232	7,587	427	3,101	4,135	103,482
5	92,006	980	370	3,089	4,118	100,563
6	515,161	7,947	695	3,868	5,157	532,828
7	176,640	847	80	68	91	177,726
8	6	1,122	0	5,435	7,246	13,810
9	0	623	0	27,567	36,756	64,947
10	706,843	8,847	574	7,624	10,166	734,055
11	240,690	5,102	1,503	3,353	4,471	255,118
12	291,465	14,780	17	1,040	1,387	308,688
13	0	3,649	0	0	0	3,649
14	65,880	3,789	290	24,016	32,022	125,998
15	0	0	0	0	0	0
16	0	0	0	0	0	0
Total	**2,447,344**	**79,692**	**4,161**	**79,162**	**105,549**	**2,715,907**

Table 5-5. Future Conditions: Annual FC Loads Delivered to the Edge-of-Stream

(cfu * 10^{10}/yr)

Reach	Livestock	Wildlife	Septic	Urban Pervious	Straight Pipes	Cows-in-streams	Urban Washoff	Permitted	Total
1	366	19	2	0	0	0	0	0	386
2	6,544	338	1	0	175	312	0	0	7,370
3	1,402	148	3	0	6	387	0	0	1,947
4	2,406	122	10	203	7	395	949	83	4,176
5	2,737	33	13	240	460	587	943	0	5,013
6	14,890	133	14	206	34	1,231	1,180	1	17,690
7	4,228	23	2	5	21	462	21	0	4,762
8	0	15	0	129	1	0	1,659	0	1,804
9	0	9	0	574	1	0	0	0	585
10	24,702	180	18	173	69	1,666	2,323	83	29,214
11	11,523	198	75	191	272	436	1,022	0	13,718
12	6,656	219	1	94	149	442	319	0	7,880
13	0	45	0	0	53	0	0	0	98
14	1,314	66	7	688	760	57	7,324	829	11,046
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
Reach Total In	**76,769**	**1,548**	**147**	**2,504**	**2,009**	**5,976**	**15,740**	**995**	**105,688**
Reach Total Out	**54,539**	**1,202**	**106**	**1,664**	**1,051**	**2,718**	**12,758**	**438**	**74,476**

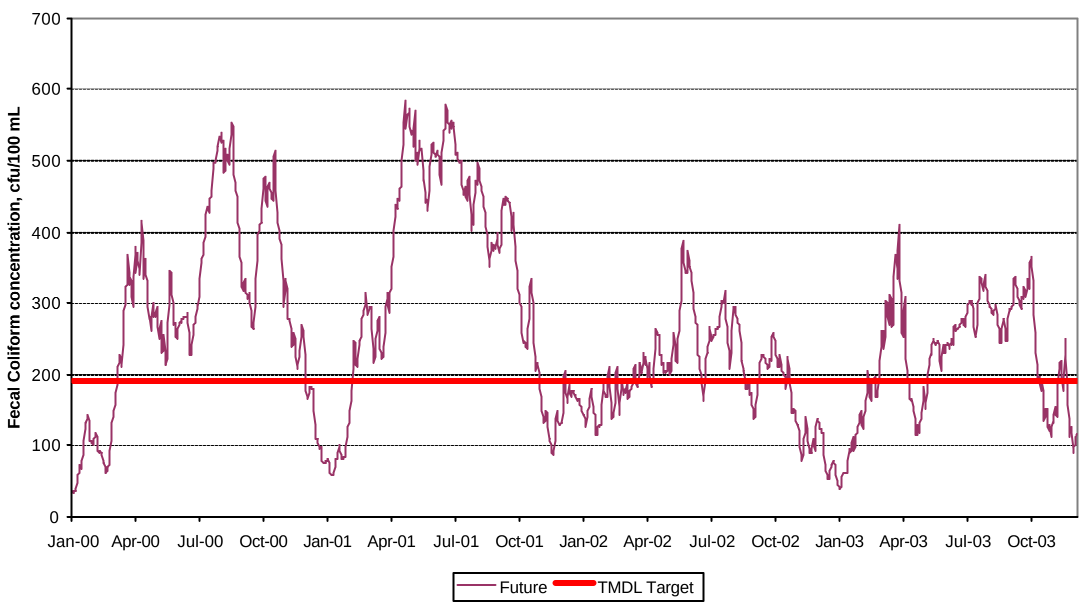

Figure 5-3. Future Conditions: 30-Day Geometric Mean FC Concentrations

The TMDL for Mountain Run is defined as a concentration, and is affected not only by loading, but also by the distribution of load over time and its relationship with flow. The 30-day geometric mean concentration relies on a combination of daily concentrations over the previous 30 days, further obscuring the relationship between load and the target TMDL. In order to describe the impact of the various sources on the 30-day geometric mean, a series of model runs was conducted that removed all loadings from each source separately to see the resulting decreases in the 30-day geometric mean. Only very minor reductions could be achieved from removing any of the land-based sources, or even from removing all of the land-based sources. Figure 5-4 shows the results of the model runs. The "No Reductions" line is the starting level for future conditions, as shown separately in Figure 5-3, and included here for reference. The "No Pervious Loads" shows the minor reductions from removing all loads from land-based sources. "No cows-in-streams" and "No urban washoff" show the impact of removing each of these two sources, independently, and represent the two sources whose removal show considerable impact on the 30-day geometric mean. As can be seen from Figure 5-4, however, the target TMDL cannot be achieved solely through reductions from one or the other of these two major influences on the 30-day geometric mean. Scenarios for meeting the TMDL target, therefore, must focus on combinations of reductions from the two sources – "cows-in-streams" and urban washoff.

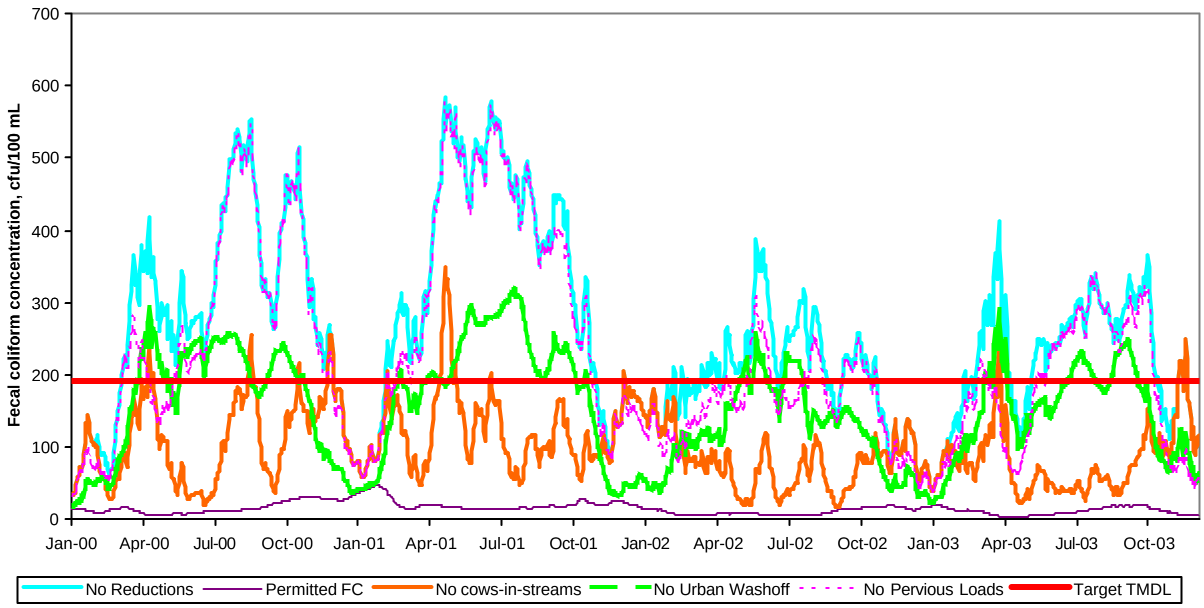

Figure 5-4. Impact of Select Scenarios on the 30-day Geometric Mean

The remaining land-based sources – wildlife, livestock-on-the-land, and urban-pervious – are all deposited on the land surface and only impact stream concentrations when transported to the stream during storm runoff. During runoff events, the larger volumes of water dilute the concentrations and mask the larger loads indicated from Table 5.2. Runoff events are also relatively short in nature, and therefore, have less impact on the geometric mean than somewhat smaller concentrations that contribute more frequently, as from impervious runoff, or continuously, as the in-stream sources. All of the alternative TMDL solutions will produce many events with FC concentrations in excess of the 1000 cfu/100 mL instantaneous standard from agricultural runoff, even though it appears to have an insignificant impact on the geometric mean. In the tables shown previously, the loading from agriculture is significantly larger than all of the other sources. However, reducing it will not significantly reduce the geometric mean concentration, because of its entry only during relatively infrequent runoff events, and because of the mathematics of the geometric mean. While impervious loading also occurs only during runoff events, loading is generated with relatively smaller runoff events making them occur more frequently than from agricultural areas, producing a greater effect on the geometric mean.

Five alternative scenarios were created to meet the TMDL target concentration, using various reductions from each of these two major sources.

- TMDL Alternative 1 removes all loads from "cows-in-streams" and takes the remaining reductions from urban washoff.
- TMDL Alternative 2 removes all loads from urban washoff, and the remaining needed reductions from "cows-in-streams".
- TMDL Alternative 3 is a combination with approximately equal reductions from each source.
- TMDL Alternative 4 was based on the reductions presented at the third public meeting, with reductions somewhat relaxed due to model revisions in the interim.
- TMDL Alternative 5 is a variation on Alternative 4, with slightly lesser reductions coming from urban washoff.

Table 5-6 lists these five alternatives, and the percent reductions that would be required by sub-watershed to meet the target TMDL. Reductions are not shown in all sub-watersheds for each source, because each source was not always present in each sub-watershed.

Each of the TMDL alternatives is further described with a table showing the distribution of loads applied to the land, and a table of loads delivered to the edge-of-stream and the watershed outlet. The tables for each alternative are shown sequentially on pages 64-68. Figures showing the resulting 30-day geometric mean fecal coliform concentrations for each alternative are shown in Figures 5-5 though 5-9.

TMDL Alternative 4 is the recommended TMDL allocation scenario because it does not lay the burden entirely on either the urban or agricultural sectors, and it is comparable and slightly less stringent than the recommended scenario presented at the third public meeting.

Table 5-6. TMDL Alternative Scenario Reductions By Sub-Watershed

TMDL Scenario	Reach	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
TMDL Alt 1	urb washoff				84	84	84	84	84	84	84	84	84		84		
	cows-in-stream		100	100	100	100	100	100			100	100	100		100		
	septic systems	100	100	100	100	100	100	100			100	100	100		100		
	straight pipes		100	100	100	100	100	100	100	100	100	100	100	100	100		
TMDL Alt 2	urb washoff				100	100	100	100	100	100	100	100	100		100		
	cows-in-stream		82	82	82	82	82	82			83	82	82		82		
	septic systems	100	100	100	100	100	100	100			100	100	100		100		
	straight pipes		100	100	100	100	100	100	100	100	100	100	100	100	100		
TMDL Alt 3	urb washoff				92	92	92	92	93	93	93	92	92		93		
	cows-in-stream		92	92	93	93	93	92			93	92	92		92		
	septic systems	100	100	100	100	100	100	100			100	100	100		100		
	straight pipes		100	100	100	100	100	100	100	100	100	100	100	100	100		
TMDL Alt 4	**urb washoff**				**95**				**95**	**96**	**95**	**95**	**95**		**95**		
	cows-in-stream		**95**	**90**	**90**	**95**	**95**	**95**			**95**	**95**	**95**		**90**		
	septic systems	**100**	**100**	**100**	**100**	**100**	**100**	**100**			**100**	**100**	**100**		**100**		
	straight pipes		**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**		
TMDL Alt 5	urb washoff				90	90	90		90	90	70	90			90		
	cows-in-stream		95	95	95	95	95	95			95	95	95		95		
	septic systems	100	100	100	100	100	100	100			100	100	100		100		
	straight pipes		100	100	100	100	100	100	100	100	100	100	100	100	100		

The Mountain Run fecal coliform TMDL for the selected scenario (TMDL Alt 4) is summarized in Table 5-7 based on reductions from projected future conditions and fecal coliform loadings.

Table 5-7. Mountain Run Fecal Coliform TMDL Summary

å**WLA**	å**LA**	**MOS**	**TMDL**
9.95 x 10^{12} cfu/yr	871.00 x 10^{12} cfu/yr	46.37 x 10^{12} cfu/yr	927.32 x 10^{12} cfu/yr

Table 5-8. TMDL Alternative 1: Annual Fecal Coliform Loads Applied to the Land

(cfu * 10^{10}/yr)

Sub-Watershed	Livestock	Wildlife	Septic	Urban Pervious	Urban Buildup	Total
1	19,431	1,099	0	0	0	20,530
2	180,678	17,833	0	0	0	198,510
3	70,312	5,488	0	0	0	75,800
4	88,232	7,587	0	3,101	786	99,705
5	92,006	980	0	3,089	782	96,857
6	515,161	7,947	0	3,868	980	527,956
7	176,640	847	0	68	17	177,572
8	6	1,122	0	5,435	1,377	7,940
9	0	623	0	27,567	6,984	35,174
10	706,843	8,847	0	7,624	1,932	725,246
11	240,690	5,102	0	3,353	849	249,994
12	291,465	14,780	0	1,040	263	307,548
13	0	3,649	0	0	0	3,649
14	65,880	3,789	0	24,016	6,084	99,770
15	0	0	0	0	0	0
16	0	0	0	0	0	0
Total	**2,447,344**	**79,692**	**0**	**79,162**	**20,054**	**2,626,251**

Table 5-9. TMDL Alternative 1: Annual FC Loads Delivered to the Edge-of-Stream

(cfu * 10^{10}/yr)

Reach	Livestock	Wildlife	Septic	Urban Pervious	Straight Pipes	Cows-in-streams	Urban Washoff	Permitted	Total
1	366	19	0	0	0	0	0	0	385
2	6,544	338	0	0	0	0	0	0	6,882
3	1,402	148	0	0	0	0	0	0	1,551
4	2,406	122	0	203	0	0	417	83	3,231
5	2,737	33	0	240	0	0	415	0	3,425
6	14,890	133	0	206	0	0	520	1	15,749
7	4,228	23	0	5	0	0	9	0	4,265
8	0	15	0	129	0	0	730	0	875
9	0	9	0	574	0	0	3,707	0	4,291
10	24,702	180	0	173	0	0	1,025	83	26,163
11	11,523	198	0	191	0	0	450	0	12,363
12	6,656	219	0	94	0	0	140	0	7,109
13	0	45	0	0	0	0	0	0	45
14	1,314	66	0	688	0	0	3,227	829	6,123
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
Reach Total In	**76,769**	**1,548**	**0**	**2,504**	**0**	**0**	**10,640**	**995**	**92,456**
Reach Total Out	**54,539**	**1,202**	**0**	**1,664**	**0**	**0**	**5,562**	**438**	**63,404**

Table 5-10. TMDL Alternative 2: Annual Fecal Coliform Loads Applied to the Land

(cfu * 10^{10}/yr)

Sub-Watershed	Livestock	Wildlife	Septic	Urban Pervious	Urban Buildup	Total
1	19,431	1,099	0	0	0	20,530
2	180,678	17,833	0	0	0	198,510
3	70,312	5,488	0	0	0	75,800
4	88,232	7,587	0	3,101	4,135	103,055
5	92,006	980	0	3,089	4,118	100,193
6	515,161	7,947	0	3,868	5,157	532,133
7	176,640	847	0	68	91	177,646
8	6	1,122	0	5,435	7,246	13,810
9	0	623	0	27,567	36,756	64,947
10	706,843	8,847	0	7,624	10,166	733,481
11	240,690	5,102	0	3,353	4,471	253,615
12	291,465	14,780	0	1,040	1,387	308,671
13	0	3,649	0	0	0	3,649
14	65,880	3,789	0	24,016	32,022	125,708
15	0	0	0	0	0	0
16	0	0	0	0	0	0
Total	**2,447,344**	**79,692**	**0**	**79,162**	**105,549**	**2,711,746**

Table 5-11. TMDL Alternative 2: Annual FC Loads Delivered to the Edge-of-Stream

(cfu * 10^{10}/yr)

Reach	Livestock	Wildlife	Septic	Urban Pervious	Straight Pipes	Cows-in-streams	Urban Washoff	Permitted	Total
1	366	19	0	0	0	0	0	0	385
2	6,544	338	0	0	0	56	0	0	6,938
3	1,402	148	0	0	0	70	0	0	1,620
4	2,406	122	0	203	0	71	0	83	2,885
5	2,737	33	0	240	0	106	0	0	3,115
6	14,890	133	0	206	0	222	0	1	15,451
7	4,228	23	0	5	0	83	0	0	4,339
8	0	15	0	129	0	0	0	0	144
9	0	9	0	574	0	0	0	0	584
10	24,702	180	0	173	0	283	0	83	25,422
11	11,523	198	0	191	0	79	0	0	11,991
12	6,656	219	0	94	0	80	0	0	7,049
13	0	45	0	0	0	0	0	0	45
14	1,314	66	0	688	0	10	0	829	2,907
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
Reach Total In	**76,769**	**1,548**	**0**	**2,504**	**0**	**1,059**	**0**	**995**	**82,875**
Reach Total Out	**54,539**	**1,202**	**0**	**1,664**	**0**	**468**	**0**	**438**	**58,310**

Table 5-12. TMDL Alternative 3: Annual Fecal Coliform Loads Applied to the Land

(cfu * 10^{10}/yr)

Sub-Watershed	Livestock	Wildlife	Septic	Urban Pervious	Urban Buildup	Total
1	19,431	1,099	0	0	0	20,530
2	180,678	17,833	0	0	0	198,510
3	70,312	5,488	0	0	0	75,800
4	88,232	7,587	0	3,101	372	99,292
5	92,006	980	0	3,089	371	96,446
6	515,161	7,947	0	3,868	464	527,440
7	176,640	847	0	68	8	177,563
8	6	1,122	0	5,435	652	7,215
9	0	623	0	27,567	3,308	31,498
10	706,843	8,847	0	7,624	915	724,230
11	240,690	5,102	0	3,353	402	249,547
12	291,465	14,780	0	1,040	125	307,409
13	0	3,649	0	0	0	3,649
14	65,880	3,789	0	24,016	2,882	96,568
15	0	0	0	0	0	0
16	0	0	0	0	0	0
Total	**2,447,344**	**79,692**	**0**	**79,162**	**9,499**	**2,615,697**

Table 5-13. TMDL Alternative 3: Annual FC Loads Delivered to the Edge-of-Stream

(cfu * 10^{10}/yr)

Reach	Livestock	Wildlife	Septic	Urban Pervious	Straight Pipes	Cows-in-streams	Urban Washoff	Permitted	Total
1	366	19	0	0	0	0	0	0	385
2	6,544	338	0	0	0	25	0	0	6,907
3	1,402	148	0	0	0	31	0	0	1,582
4	2,406	122	0	203	0	28	255	83	3,097
5	2,737	33	0	240	0	41	254	0	3,305
6	14,890	133	0	206	0	86	318	1	15,634
7	4,228	23	0	5	0	37	6	0	4,298
8	0	15	0	129	0	0	403	0	547
9	0	9	0	574	0	0	2,046	0	2,629
10	24,702	180	0	173	0	117	565	83	25,821
11	11,523	198	0	191	0	35	276	0	12,223
12	6,656	219	0	94	0	35	86	0	7,090
13	0	45	0	0	0	0	0	0	45
14	1,314	66	0	688	0	5	1,781	829	4,682
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
Reach Total In	**76,769**	**1,548**	**0**	**2,504**	**0**	**439**	**5,990**	**995**	**88,246**
Reach Total Out	**54,539**	**1,202**	**0**	**1,664**	**0**	**200**	**3,129**	**438**	**61,172**

Table 5-14. TMDL Alternative 4: Annual Fecal Coliform Loads Applied to the Land

(cfu * 10^{10}/yr)

Sub-Watershed	Livestock	Wildlife	Septic	Urban Pervious	Urban Buildup	Total
1	19,431	1,099	0	0	0	20,530
2	180,678	17,833	0	0	0	198,510
3	70,312	5,488	0	0	0	75,800
4	88,232	7,587	0	3,101	207	99,127
5	92,006	980	0	3,089	4,118	100,193
6	515,161	7,947	0	3,868	5,157	532,133
7	176,640	847	0	68	91	177,646
8	6	1,122	0	5,435	362	6,925
9	0	623	0	27,567	1,470	29,660
10	706,843	8,847	0	7,624	508	723,823
11	240,690	5,102	0	3,353	224	249,368
12	291,465	14,780	0	1,040	69	307,354
13	0	3,649	0	0	0	3,649
14	65,880	3,789	0	24,016	1,601	95,287
15	0	0	0	0	0	0
16	0	0	0	0	0	0
Total	**2,447,344**	**79,692**	**0**	**79,162**	**13,808**	**2,620,005**

Table 5-15. TMDL Alternative 4: Annual FC Loads Delivered to the Edge-of-Stream

(cfu * 10^{10}/yr)

Reach	Livestock	Wildlife	Septic	Urban Pervious	Straight Pipes	Cows-in-streams	Urban Washoff	Permitted	Total
1	366	19	0	0	0	0	0	0	385
2	6,544	338	0	0	0	16	0	0	6,897
3	1,402	148	0	0	0	39	0	0	1,589
4	2,406	122	0	203	0	40	175	83	3,028
5	2,737	33	0	240	0	29	943	0	3,982
6	14,890	133	0	206	0	62	1,180	1	16,471
7	4,228	23	0	5	0	23	21	0	4,300
8	0	15	0	129	0	0	306	0	450
9	0	9	0	574	0	0	1,284	0	1,868
10	24,702	180	0	173	0	83	430	83	25,651
11	11,523	198	0	191	0	22	189	0	12,123
12	6,656	219	0	94	0	22	59	0	7,050
13	0	45	0	0	0	0	0	0	45
14	1,314	66	0	688	0	6	1,352	829	4,255
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
Reach Total In	**76,769**	**1,548**	**0**	**2,504**	**0**	**341**	**5,938**	**995**	**88,095**
Reach Total Out	**54,539**	**1,202**	**0**	**1,664**	**0**	**160**	**3,236**	**438**	**61,238**

Table 5-16. TMDL Alternative 5: Annual Fecal Coliform Loads Applied to the Land

(cfu * 10^{10}/yr)

Sub-Watershed	Livestock	Wildlife	Septic	Urban Pervious	Urban Buildup	Total
1	19,431	1,099	0	0	0	20,530
2	180,678	17,833	0	0	0	198,510
3	70,312	5,488	0	0	0	75,800
4	88,232	7,587	0	3,101	414	99,333
5	92,006	980	0	3,089	412	96,487
6	515,161	7,947	0	3,868	516	527,492
7	176,640	847	0	68	91	177,646
8	6	1,122	0	5,435	725	7,288
9	0	623	0	27,567	3,676	31,866
10	706,843	8,847	0	7,624	5,083	728,398
11	240,690	5,102	0	3,353	447	249,591
12	291,465	14,780	0	1,040	1,387	308,671
13	0	3,649	0	0	0	3,649
14	65,880	3,789	0	24,016	3,202	96,888
15	0	0	0	0	0	0
16	0	0	0	0	0	0
Total	**2,447,344**	**79,692**	**0**	**79,162**	**15,951**	**2,622,148**

Table 5-17. TMDL Alternative 5: Annual FC Loads Delivered to the Edge-of-Stream

(cfu * 10^{10}/yr)

Reach	Livestock	Wildlife	Septic	Urban Pervious	Straight Pipes	Cows-in-streams	Urban Washoff	Permitted	Total
1	366	19	0	0	0	0	0	0	385
2	6,544	338	0	0	0	16	0	0	6,897
3	1,402	148	0	0	0	19	0	0	1,570
4	2,406	122	0	203	0	20	302	83	3,136
5	2,737	33	0	240	0	29	301	0	3,340
6	14,890	133	0	206	0	62	377	1	15,668
7	4,228	23	0	5	0	23	21	0	4,300
8	0	15	0	129	0	0	529	0	673
9	0	9	0	574	0	0	2,685	0	3,269
10	24,702	180	0	173	0	83	1,466	83	26,688
11	11,523	198	0	191	0	22	326	0	12,260
12	6,656	219	0	94	0	22	319	0	7,310
13	0	45	0	0	0	0	0	0	45
14	1,314	66	0	688	0	3	2,337	829	5,237
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
Reach Total In	**76,769**	**1,548**	**0**	**2,504**	**0**	**299**	**8,663**	**995**	**90,778**
Reach Total Out	**54,539**	**1,202**	**0**	**1,664**	**0**	**136**	**4,558**	**438**	**62,536**

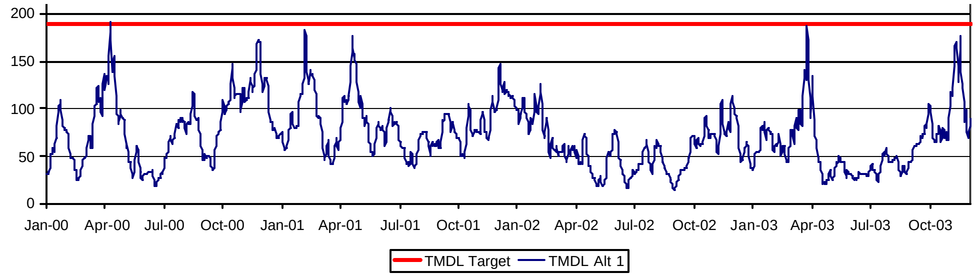

Figure 5-5. TMDL Alternative 1: 30-Day Geometric Mean FC Concentrations

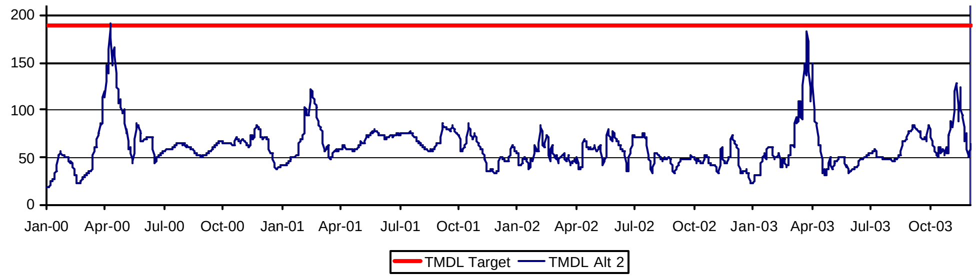

Figure 5-6. TMDL Alternative 2: 30-Day Geometric Mean FC Concentrations

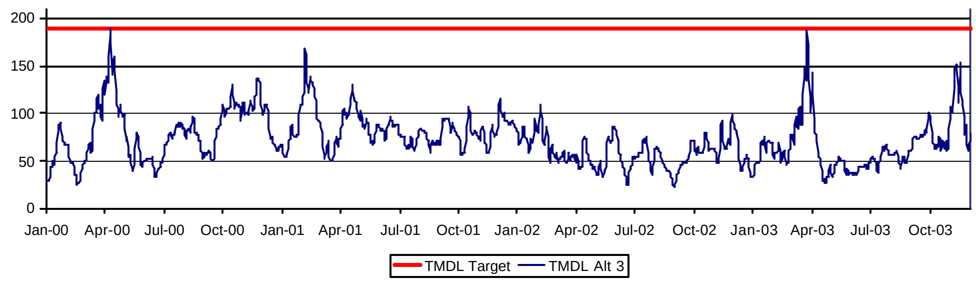

Figure 5-7. TMDL Alternative 3: 30-Day Geometric Mean FC Concentrations

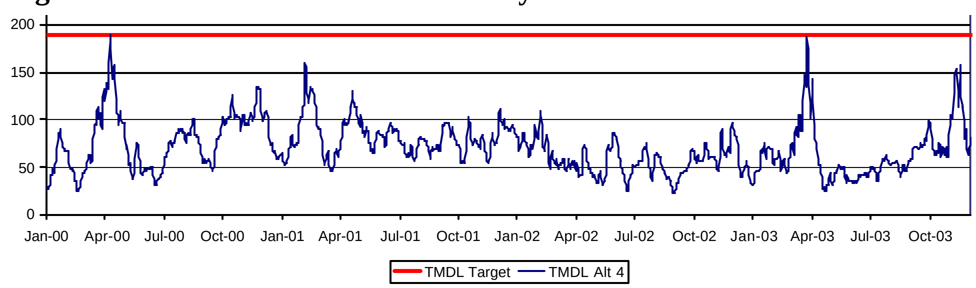

Figure 5-8. TMDL Alternative 4: 30-Day Geometric Mean FC Concentrations

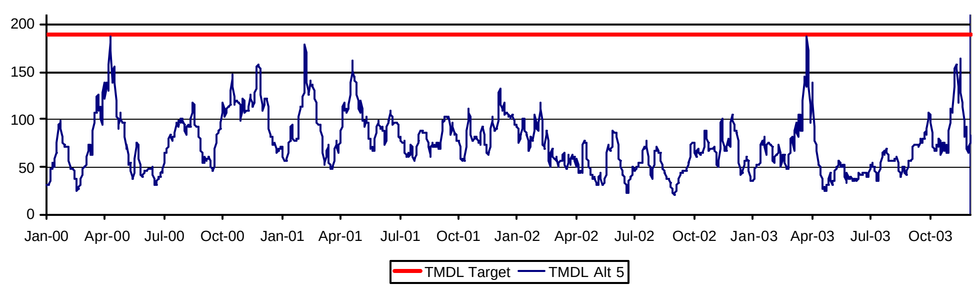

Figure 5-9. TMDL Alternative 5: 30-Day Geometric Mean FC Concentrations

6.0 IMPLEMENTATION

6.1 Follow-up Monitoring

The Department of Environmental Quality will maintain the existing monitoring stations in the Mountain Run watershed in accordance with its ambient monitoring program. VADEQ and VADCR will continue to use data from these monitoring stations to evaluate reductions in fecal bacteria counts and the effectiveness of the TMDL in attaining and maintaining water quality standards.

6.2 TMDL Implementation Process

The goal of this TMDL is to establish a three-step path that will lead to expeditious attainment of water quality standards. The first step in this process was to develop the TMDL. The second step is to develop a TMDL implementation plan, and the final step is to implement the TMDL and attain water quality standards.

Section 303(d) of the Clean Water Act (CWA) and current EPA regulations do not require the development of implementation plans. However, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQ MIRA) directs VADEQ in section 62.1-44.19.7 to "develop and implement a plan to achieve fully supporting status for impaired waters". The Act also establishes that the implementation plan shall include the "date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated cost, benefits and environmental impact" of addressing the impairments (VA Code 62.1-44.19.7).

EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process". The listed elements include implementation actions/management measures, time line, legal or regulatory controls, time required to attain water quality standards, monitoring plan and milestones for attaining water quality standards.

The corrective action and cost assessment required under WQMIRA is an essential element of the TMDL process. By performing the corrective action and cost assessment during the development of the implementation plan, the State will generate information that can be used to confirm the sources needing controls and the efficacy of the controls and to prioritize potential corrective actions.

Since this TMDL consists primarily of NPS load allocations, VADCR will have the lead for the development of the implementation plan. Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of VADEQ, VADCR and other cooperating agencies.

Once developed, VADEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan, in accordance with the CWA's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and VADEQ, VADEQ also submitted a draft Continuous Planning Process to EPA in which VADEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

One potential source of funding for TMDL implementation is Section 319 of the Clean Water Act. In response to the federal Clean Water Action Plan, Virginia developed a Unified Watershed Assessment that identifies watershed priorities. Watershed restoration activities, such as TMDL implementation, within these priority watersheds are eligible for Section 319 funding. Increases in Section 319 funding in future years will be targeted towards TMDL implementation and watershed restoration. Other funding sources for implementation include the USDA's CREP program, the state revolving loan program, and the VA Water Quality Improvement Fund.

6.3 Stage I Implementation Goal

DEQ intends for this TMDL to be implemented through best management practices (BMPs) in the watershed. Implementation will occur in stages. The benefits of staged implementation are, 1. as stream monitoring continues to occur, it allows for water quality improvements to be recorded as they are being achieved; 2. it provides a measure of quality control, given the uncertainties which exist in any model; 3. it provides a mechanism for developing public support; 4. it helps to ensure the most cost effective practices are implemented initially; and 5. it allows for the evaluation of the adequacy of the TMDL in achieving the water quality standard. Stage I goals for BMP implementation will be established as part of the implementation plan development process.

One potential endpoint for a stage I implementation goal is an exceedence rate of 10% of the instantaneous fecal coliform water quality standard - 1,000 cfu/100mL. This corresponds to the criteria used for listing waters on the 303(d) TMDL list. Stage I reductions will include, as a minimum, elimination of any human sources of fecal coliforms, such as existing “straight pipes” and faulty septic systems. As with the TMDL allocations, the Stage I implementation goal will be set in terms of reductions from the two major influences on the geometric mean in the watershed - "cows-in-streams" and storm washoff from urban impervious areas. In addition to "straight pipes" and faulty septic systems, an allocation developed for Mountain Run to meet an exceedence rate of 10% of the instantaneous fecal coliform standard would require reducing loads from "cows-in-stream" and urban washoff. For example, management practices that might be appropriate for controlling urban wash-off and that could be readily implemented may include the following:

- More restrictive ordinances to reduce fecal loads from pets
- Improved garbage collection and control
- A sanitary sewer inspection and management program
- Improved street cleaning.

6.4 Water Quality Standards Review

The VADEQ and VADCR have developed fecal coliform TMDLs for a number of impaired waters in the State. In some of the streams, fecal coliform bacteria counts contributed by wildlife result in standards violations, particularly during base flow conditions. Wildlife densities obtained from the Department of Game and Inland Fisheries and analysis or "typing" of the fecal coliform bacteria show that the high densities of muskrat, beaver, and waterfowl are responsible for the elevated fecal bacteria counts in these streams. In order to address this issue, the Commonwealth is currently reviewing its water quality standards with respect to fecal coliform bacteria. The issues under review are 1) designated uses, 2) indicator species, and 3) applicable flow conditions. Another option that EPA allows for the states is to adopt site specific criteria based on natural background levels of fecal coliforms. The State must demonstrate that the source of fecal contamination is natural and uncontrollable by effluent limitations and BMPs.

6.4.1 Designated Uses

All waters in the Commonwealth have been designated as "primary contact" for the swimming use regardless of size, depth, location, water quality or actual use. The fecal coliform bacteria standard is described in 9 VAC 25-260-170 and on page 1–3 in Section 1 of this report. This standard is to be met during all stream flow levels and was established to protect bathers from ingestion of potentially harmful bacteria. However, many headwater streams are small and shallow during base flow conditions when surface runoff has minimal influence on stream flow. Even in pools, these shallow streams do not allow full body immersion during periods of base flow. In larger streams, lack of public access often precludes the swimming use.

In the TMDL public participation process, the residents in these watersheds often report that " people do not swim in this stream." It is obvious that many streams within the state are not used for recreational purposes. In many cases, insufficient depth of the streams along with other physical factors and lack of public accessibility do not provide suitable conditions for swimming or primary contact recreation.

Recognizing that all waters in the Commonwealth are not used extensively for swimming, VA is currently looking at re-designation of the swimming use based on actual swimming frequency and risk assessment. The new designation of the swimming use could contain the following 4 levels:

- Designated bathing beach (currently all waters protected to this level),
- Moderate swimming,
- Low swimming, and
- Infrequent swimming.

Each of the four swimming use levels would have protection criterion based on risk analysis. The current high levels of protection would continue to be applied to waters in which people are more likely to engage in an activity that results in the ingestion of water. The primary contact recreational uses recommended above are from EPA's Ambient Water Quality Criteria for Bacteria, 1986.

The re-designation of the current swimming use may require the completion of a use attainability analysis. A Use Attainability Analysis (UAA), is a structured scientific assessment of the factors affecting the attainment of the use which may include physical, chemical, biological, and economic factors as described in the Federal Regulations. The stakeholders in the watershed, Virginia, and EPA will have an opportunity to comment on these special studies.

6.4.2 Indicator Species

EPA has recommended that all States adopt an *E. coli* or enterococci standard for fresh water and enterococci criteria for marine waters by 2003. EPA is pursuing the States' adoption of these standards because there is a stronger correlation between the concentration of these organisms (*E. coli* and enterococci) and the incidence of gastrointestinal illness than with fecal coliform. *E-coli* and enterococci are both bacteriological organisms that can be found in the intestinal tract of warm-blooded animals. Like fecal coliform bacteria, these organisms indicate the presence of fecal contamination. The adoption of the *E. coli* and enterococci standard is scheduled for 2002 in Virginia.

6.4.3 Flow Condition

Most states apply their water quality standards only to flows above a statistical low flow frequency that is defined as a 7-day average occurring once every 10 years (7Q10). However Virginia's fecal coliform bacteria standard is applied to all flows. Some head water streams have very minimal flow during periods of low precipitation or droughts. During such low flow events, the counts of fecal coliform bacteria deposited directly into the stream are concentrated because the small flow is unable to dilute the deposition of wastes. In order to attain standards during low flow conditions, it is necessary to reduce the amount of waste deposited directly to the stream. Sources of these wastes include cattle in-stream, wildlife in-stream, septic systems, and wastes conveyed directly to the stream from milking parlors. By applying the standard only to flows greater than 7Q10, the TMDL would not need to insure the attainment of standards during extreme drought flow conditions when stream flow falls below 7Q10.

7.0 Public Participation

The first public meeting was held at the Culpeper Middle School in Culpeper, Virginia on June 2, 1999 to discuss the development of the TMDL, and was public noticed on May 24, 1999 in the Virginia Register. Letters announcing the meeting were sent to stakeholders in the watersheds, including the Culpeper Soil and Water Conservation District, Culpeper Farm Bureau, the Mountain Run Watershed Citizen Advisory and Technical Advisory Committees, and a host of other groups targeted by the local planning team. Posters announcing the public meeting were also placed in prominent gathering places around the watershed. Copies of the presentation materials were available for public distribution at the meeting. The public comment period ended on June 23, 1999.

The second public meeting was held at the Culpeper Middle School on September 27, 1999 to discuss the hydrologic calibration and input data for the TMDL. This meeting was public noticed on September 13, 1999 in the Virginia Register and in the Culpeper Exponent on September 22,1999. Posters announcing the public meeting were also placed in prominent gathering places around the watershed. Copies of the presentation were available for public distribution at the meeting. The public comment period ended on October 12, 1999.

The third public meeting was held in Culpeper on May 10, 2000 to discuss the draft TMDL. The public notice was placed in the Virginia Register on April 24, 2000. Copies of the draft TMDL were available for public distribution at the time of public notice and at the meeting. The public comment period ended on May 24, 2000, but on request was extended through September 30, 2000.

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Appendix A.

DEQ Monitoring Data – Mountain Run Watershed, 1987-1997

DEQ Monitoring Data – Mountain Run Watershed, 1987-1997

DEQ Station	Mo	Day	Yr	USGS Daily Flow (cfs)	Fecal Coliform (cfu/100mL)
MTN000.59	5	28	91	4.6	45
MTN000.59	6	26	91	4.7	78
MTN000.59	7	29	91	9.1	460
MTN000.59	8	27	91	0.96	170
MTN000.59	9	30	91	1.9	
MTN000.59	10	21	91	1.5	78
MTN000.59	11	18	91	1.8	20
MTN000.59	12	16	91	7.4	5400
MTN000.59	1	28	92	11	
MTN000.59	2	25	92	16	170
MTN000.59	3	25	92	12	230
MTN000.59	4	9	92	10	20
MTN000.59	5	5	92	9.3	170
MTN000.59	6	11	92	11	
MTN000.59	7	9	92	4.9	200
MTN000.59	8	13	92	10	600
MTN000.59	9	14	92	8.1	200
MTN000.59	10	20	92	6	100
MTN000.59	11	23	92	218	8000
MTN000.59	12	21	92	22	2700
MTN000.59	1	26	93	23	100
MTN000.59	2	23	93	51	1200
MTN000.59	3	22	93	75	1700
MTN000.59	4	19	93	37	1400
MTN000.59	5	17	93	56	8000
MTN000.59	6	17	93	7.8	
MTN000.59	7	15	93	3.2	400
MTN000.59	8	12	93	4.5	700
MTN000.59	9	7	93	2.2	100
MTN000.59	10	7	93	2.2	100
MTN000.59	11	22	93	5.5	200
MTN000.59	1	31	94	26	
MTN000.59	2	17	94	50	1600
MTN000.59	3	17	94	24	100
MTN000.59	5	12	94	11	300
MTN000.59	6	2	94	4.9	100

DEQ Station	Mo	Day	Yr	USGS Daily Flow (cfs)	Fecal Coliform (cfu/100mL)
MTN000.59	7	19	94	11	4200
MTN000.59	8	11	94	7.2	200
MTN000.59	9	8	94	5.1	100
MTN000.59	10	18	94	7.2	200
MTN000.59	12	20	94	11	100
MTN000.59	1	25	95	16	800
MTN000.59	2	14	95	8.4	100
MTN000.59	3	23	95	12	600
MTN000.59	4	26	95	10	
MTN000.59	5	24	95	5.8	100
MTN000.59	6	21	95	4.6	100
MTN000.59	7	20	95	8.9	200
MTN000.59	8	23	95	2.9	200
MTN000.59	11	8	95	14	2500
MTN000.59	1	24	96	48	300
MTN000.59	2	22	96	35	1500
MTN000.59	3	21	96	33	2000
MTN000.59	4	15	96	16	100
MTN000.59	5	21	96	13	100
MTN000.59	6	27	96	15	100
MTN000.59	7	24	96	12	300
MTN000.59	8	27	96	7.4	200
MTN000.59	9	26	96	10	
MTN000.59	11	20	96	13	300
MTN000.59	12	18	96	27	8000
MTN000.59	1	29	97	25	200
MTN000.59	2	20	97	21	100
MTN000.59	3	26	97	22	200
MTN000.59	4	23	97	14	100
MTN000.59	5	22	97	6.6	100
MTN000.59	7	24	97	27	8000
MTN000.59	4	1	87	18	300
MTN022.49	5	13	87	12	200
MTN022.49	6	24	87	5.1	100
MTN022.49	12	19	90	21	
MTN022.49	4	24	91	16	
MTN022.49	6	18	91	21	
MTN022.49	11	12	91	1.9	1600

DEQ Station	Mo	Day	Yr	USGS Daily Flow (cfs)	Fecal Coliform (cfu/100mL)
MTN022.49	12	19	91	5.8	3500
MTN022.49	3	23	92	14	45
MTN022.49	6	24	92	8.6	
MTN022.49	9	1	92	3	300
MTN022.49	12	14	92	78	500
MTN022.49	3	25	93	62	200
MTN022.49	6	8	93	25	1200
MTN022.49	9	7	93	2.2	100
MTN022.49	12	16	93	1.8	100
MTN022.49	3	16	94	2.7	100
MTN022.49	9	29	94	8.4	100
MTN022.49	12	28	94	8.1	100
MTN022.49	3	16	95	15	100
MTN022.49	9	25	95	6.9	1800
MTN022.49	1	2	96	39	600
MTN022.49	3	20	96	60	100
MTN022.49	6	27	96	15	100
MTN022.49	9	24	96	12	100
MTN022.49	1	22	97	20	100
MTN022.49	4	21	97	11	100
MTN022.49	7	29	97	4.3	400
MTN000.59	8	28	97		100
MTN000.59	9	10	97		100
MTN000.59	10	8	97		200
MTN022.49	10	28	97		100
MTN000.59	11	18	97		300
MTN000.59	12	17	97		200

Appendix B.

RRPDC/BSE Monitoring Data 1996-1998

Sample Collection By
Rappahannock-Rapidan Planning District Commission

Sample Analysis and QA/QC By
Biological Systems Engineering (BSE) Department, Virginia Tech

RRPDC/BSE Monitoring Data 1996-1998

Date	Set#	WS#	Site	Total Coliform (cfu/100mL)	Fecal Coliform[1] (cfu/100mL)	E. coli (cfu/100mL)
10/03/96	1	1	MR1	2700	118	0
10/03/96	1	2	MR2	2900	155	182
10/03/96	1	3	MR3	8000	100	91
10/03/96	1	5	MR5	6800	280	0
10/03/96	1	6	MR6	7200	3900	3100
10/03/96	1	7	MR7	3000	480	91
10/03/96	1	8	MR8	6600	490	364
10/03/96	1	9	MR9	3600	64	273
10/03/96	1	10	MR10	2000	200	455
10/03/96	1	11	MR11	2000	100	182
11/07/96	2	1	MR1	818	0	0
11/07/96	2	2	MR2	2800	136	0
11/07/96	2	3	MR3	1273	73	91
11/07/96	2	5	MR5	909	73	0
11/07/96	2	6	MR6	6600	5000	3400
11/07/96	2	7	MR7	2091	270	273
11/07/96	2	8	MR8	5300	470	364
11/07/96	2	9	MR9	6000	27	273
11/07/96	2	10	MR10	1182	91	91
11/07/96	2	11	MR11	1636	27	0
12/05/96	3	7	MR7	1909	230	91
12/05/96	3	8	MR8	1364	600	273
12/05/96	3	10	MR10	2000	46	455
12/05/96	3	11	MR11	2400	200	182
12/16/96	3A	1	MR1	3300	200	91
12/16/96	3A	2	MR2	49000	600	818
12/16/96	3A	5	MR5	23000	240	91
12/16/96	3A	6	MR6	3100	540	273
12/16/96	3A	9	MR9	3300	40	0
01/22/97	4	1	MR1	182	15	0
01/22/97	4	2	MR2	4100	250	182
01/22/97	4	3	MR3	727	72	182
01/22/97	4	5	MR5	1364	33	0
01/22/97	4	6	MR6	909	600	546
01/22/97	4	7	MR7	1636	350	636
01/22/97	4	8	MR8	1818	200	273
01/22/97	4	9	MR9	4000	23	91
01/22/97	4	10	MR10	2000	44	182
01/22/97	4	11	MR11	1546	18	0
02/20/97	5	1	MR1	91	18	0
02/20/97	5	2	MR2	1364	18	91
02/20/97	5	3	MR3	91	9	0
02/20/97	5	5	MR5	91	64	0
02/20/97	5	6	MR6	91	46	0
02/20/97	5	7	MR7	91	46	0

Date	Set#	WS#	Site	Total Coliform (cfu/100mL)	Fecal Coliform[1] (cfu/100mL)	E. coli (cfu/100mL)
02/20/97	5	8	MR8	636	73	0
02/20/97	5	9	MR9	182	82	0
02/20/97	5	10	MR10	1818	55	91
02/20/97	5	11	MR11	1273	9	91
03/06/97	6	1	MR1	2000	250	273
03/06/97	6	2	MR2	8000	2200	1273
03/06/97	6	3	MR3	5000	600	909
03/06/97	6	5	MR5	3100	410	455
03/06/97	6	6	MR6	32000	3200	1182
03/06/97	6	7	MR7	2800	2000	546
03/06/97	6	8	MR8	3800	270	1091
03/06/97	6	9	MR9	4200	146	727
03/06/97	6	10	MR10	2800	600	1364
03/06/97	6	11	MR11	2900	570	364
04/03/97	7	1	MR1	364	100	0
04/03/97	7	2	MR2	909	230	91
04/03/97	7	3	MR3	1364	18	273
04/03/97	7	5	MR5	727	173	0
04/03/97	7	6	MR6	909	600	455
04/03/97	7	7	MR7	455	290	364
04/03/97	7	8	MR8	1364	109	182
04/03/97	7	9	MR9	818	18	91
04/03/97	7	10	MR10	273	109	0
04/03/97	7	11	MR11	364	164	0
05/01/97	8	1	MR1	2100	52	46
05/01/97	8	2	MR2	800	118	200
05/01/97	8	3	MR3	2800	94	109
05/01/97	8	5	MR5	780	120	210
05/01/97	8	6	MR6	7900	4000	2700
05/01/97	8	7	MR7	4100	410	360
05/01/97	8	8	MR8	4200	300	300
05/01/97	8	9	MR9	2500	100	146
05/01/97	8	10	MR10	760	350	340
05/01/97	8	11	MR11	620	200	200
05/29/97	9	1	MR1	2500	78	66
05/29/97	9	2	MR2	7600	230	200
05/29/97	9	3	MR3	2900	200	220
05/29/97	9	5	MR5	3000	280	240
05/29/97	9	6	MR6	2500	600	300
05/29/97	9	7	MR7	3300	100	91
05/29/97	9	8	MR8	3700	350	350
05/29/97	9	9	MR9	8500	300	500
05/29/97	9	10	MR10	700	80	230
05/29/97	9	11	MR11	2300	60	55
06/25/97	10	1	MR1	5600	260	240
06/25/97	10	2	MR2	8000	2500	2100
06/25/97	10	3	MR3	4300	360	390
06/25/97	10	5	MR5	6400	2400	2100
06/25/97	10	6	MR6	8000	2900	2500

Date	Set#	WS#	Site	Total Coliform (cfu/100mL)	Fecal Coliform[1] (cfu/100mL)	E. coli (cfu/100mL)
06/25/97	10	7	MR7	2300	390	350
06/25/97	10	8	MR8	3300	430	430
06/25/97	10	9	MR9	8000	3300	4600
06/25/97	10	10	MR10	800	600	750
06/25/97	10	11	MR11	640	220	200
07/29/97	11	1	MR1	3900	200	210
07/29/97	11	2	MR2	8000	636	1090
07/29/97	11	3	MR3	2800	400	410
07/29/97	11	5	MR5	3000	600	380
07/29/97	11	6	MR6	5900	4500	370
07/29/97	11	7	MR7	3700	73	9
07/29/97	11	8	MR8	4600	200	650
07/29/97	11	9	MR9	38000	270	182
07/29/97	11	10	MR10	800	36	36
07/29/97	11	11	MR11	2000	64	46
09/03/97	13	1	MR1	8000	270	182
09/03/97	13	2	MR2	7400	340	727
09/03/97	13	3	MR3	5600	600	636
09/03/97	13	5	MR5	6000	250	273
09/03/97	13	6	MR6	7800	1000	2800
09/03/97	13	7	MR7	2300	118	0
09/03/97	13	8	MR8	5900	290	273
09/03/97	13	10	MR10	3100	330	350
09/03/97	13	11	MR11	47000	600	2700
09/23/97	14	1	MR1	3000	36	182
09/23/97	14	2	MR2	8000	9	273
09/23/97	14	3	MR3	3600	510	273
09/23/97	14	5	MR5	1546	136	182
09/23/97	14	6	MR6	4300	36	636
09/23/97	14	7	MR7	1727	109	0
09/23/97	14	8	MR8	4200	2300	182
09/23/97	14	10	MR10	4800	82	818
09/23/97	14	11	MR11	2000	27	0
10/20/97	15	1	MR1	2300	210	364
10/20/97	15	2	MR2	2900	270	636
10/20/97	15	5	MR5	1818	250	91
10/20/97	15	6	MR6	6500	5500	510
10/20/97	15	8	MR8	1546	600	546
10/20/97	15	11	MR11	1000	260	91
10/20/97	15	22	MR22	4300	73	0
10/20/97	15	55	MR55	5400	330	182
10/20/97	15	66	MR66	8300	690	1091
10/20/97	15	88	MR88	3400	610	1182
11/20/97	16	1	MR1	273	0	0
11/20/97	16	5	MR5	1273	0	0
11/20/97	16	6	MR6	2300	240	91
11/20/97	16	8	MR8	2000	191	182
11/20/97	16	9	MR9	2500	82	0
11/20/97	16	11	MR11	1000	109	0

Date	Set#	WS#	Site	Total Coliform (cfu/100mL)	Fecal Coliform[1] (cfu/100mL)	E. coli (cfu/100mL)
11/20/97	16	55	MR55	1727	36	0
11/20/97	16	66	MR66	2800	100	91
11/20/97	16	67	MR67	2273	173	91
11/20/97	16	88	MR88	1546	100	91
12/16/97	17	1	MR1	91	3	0
12/16/97	17	5	MR5	364	64	0
12/16/97	17	6	MR6	2091	230	0
12/16/97	17	8	MR8	1455	96	91
12/16/97	17	9	MR9	636	0	0
12/16/97	17	11	MR11	455	60	0
12/16/97	17	55	MR55	1727	32	0
12/16/97	17	66	MR66	1546	500	182
12/16/97	17	67	MR67	1818	96	91
12/16/97	17	88	MR88	546	280	273
01/26/98	18	1	MR1	700	280	280
01/26/98	18	5	MR5	640	240	200
01/26/98	18	6	MR6	800	350	340
01/26/98	18	8	MR8	610	340	300
01/26/98	18	9	MR9	800	84	82
01/26/98	18	11	MR11	700	230	127
01/26/98	18	55	MR55	730	350	290
01/26/98	18	66	MR66	490	210	91
01/26/98	18	67	MR67	840	470	450
01/26/98	18	88	MR88	530	290	290
02/26/98	19	1	MR1	450	76	73
02/26/98	19	5	MR5	700	120	118
02/26/98	19	6	MR6	1364	73	0
02/26/98	19	8	MR8	290	118	55
02/26/98	19	11	MR11	500	52	45
02/26/98	19	55	MR55	250	98	82
02/26/98	19	66	MR66	1000	10	0
02/26/98	19	67	MR67	455	91	91
02/26/98	19	88	MR88	310	94	91
02/26/98	19	99	MR99	220	13	9
03/31/98	20	1	MR1	390	106	100
03/31/98	20	5	MR5	800	94	82
03/31/98	20	6	MR6	2500	720	600
03/31/98	20	8	MR8	760	112	109
03/31/98	20	9	MR9	2600	98	55
03/31/98	20	11	MR11	750	420	260
03/31/98	20	55	MR55	330	72	64
03/31/98	20	66	MR66	2900	680	510
03/31/98	20	67	MR67	3500	2800	2300
03/31/98	20	88	MR88	840	118	100
04/29/98	21	1	MR1	5200	60	9
04/29/98	21	5	MR5	830	86	0
04/29/98	21	6	MR6	2800	680	173
04/29/98	21	8	MR8	800	240	46
04/29/98	21	9	MR9	580	360	55
04/29/98	21	11	MR11	450	132	27

Date	Set#	WS#	Site	Total Coliform (cfu/100mL)	Fecal Coliform[1] (cfu/100mL)	E. coli (cfu/100mL)
04/29/98	21	55	MR55	3100	600	64
04/29/98	21	66	MR66	7600	670	209
04/29/98	21	67	MR67	2600	120	109
04/29/98	21	88	MR88	2900	120	100
05/28/98	22	1	MR1	2700	290	100
05/28/98	22	5	MR5	2900	440	280
05/28/98	22	6	MR6	59000	3300	2700
05/28/98	22	8	MR8	8200	500	460
05/28/98	22	9	MR9	26000	240	209
05/28/98	22	11	MR11	2900	200	164
05/28/98	22	55	MR55	3000	270	127
05/28/98	22	66	MR66	65000	2900	2100
05/28/98	22	67	MR67	54000	2800	2500
05/28/98	22	88	MR88	5600	690	590
06/25/98	23	1	MR1	3000	280	136
06/25/98	23	5	MR5	2400	270	240
06/25/98	23	6	MR6	39000	4300	4000
06/25/98	23	8	MR8	5600	630	470
06/25/98	23	11	MR11	8100	530	510
06/25/98	23	55	MR55	6500	670	600
06/25/98	23	66	MR66	26000	2500	2400
06/25/98	23	67	MR67	23000	4000	3800
06/25/98	23	88	MR88	6300	660	500
06/25/98	23	99	MR99	20000	400	310
07/27/98	24	1	MR1	7000	450	200
07/27/98	24	5	MR5	4300	260	200
07/27/98	24	6	MR6	40000	300	280
07/27/98	24	8	MR8	8000	164	136
07/27/98	24	11	MR11	7600	490	400
07/27/98	24	55	MR55	6600	680	590
07/27/98	24	66	MR66	27000	210	182
07/27/98	24	67	MR67	30000	520	490
07/27/98	24	88	MR88	8500	700	610
07/27/98	24	99	MR99	23000	5500	690
08/10/98	25	1	MR1	8000	470	210
08/10/98	25	5	MR5	5700	250	210
08/10/98	25	6	MR6	43000	2100	2000
08/10/98	25	8	MR8	38000	2700	818
08/10/98	25	11	MR11	8000	390	380
08/10/98	25	55	MR55	9900	690	400
08/10/98	25	66	MR66	25000	1727	1455
08/10/98	25	67	MR67	73000	6500	5900
08/10/98	25	88	MR88	9100	750	610
08/10/98	25	99	MR99	24000	6900	1818

[1] Prior to November 1997, many samples were producing unexpected concentrations of fecal coliform less than *E. coli*. Fecal coliform includes a number of different bacteria species, one of which is *E. coli.* Fecal coliform counts, therefore, should always be equal to or greater than the *E. coli* count. In November 1997, the range of dilutions used in the fecal coliform analysis was adjusted to provide for a more accurate count and concentration determination. The new dilutions have resulted in the expected balance between these two related bacteria types.

Appendix C.

Additional RRPDC/BSE Water Quality Monitoring Data, 1998

Sample Collection By

Rappahannock-Rapidan Planning District Commission
and
Biological Systems Engineering (BSE) Department, Virginia Tech

Sample Analysis By

Biological Systems Engineering (BSE) Department, Virginia Tech

Additional RRPDC/BSE Water Quality Monitoring Data, 1998

Date	Time	Site Code	Total Coliform (cfu/100mL)	Fecal Coliform (cfu/100mL)	E. coli (cfu/100mL)	Enterococcus (cfu/100mL)
02-23-98	11:10	MR-6	8000	6000	5100	3900
02-23-98	11:21	FC-6b	60000	2800	1273	4500
02-23-98	11:28	FC-6c	880	710	530	300
02-23-98	10:26	MR-66	800	600	155	370
02-23-98	10:33	FC-6e	7400	2500	2100	290
02-23-98	11:46	FC-6f	2400	650	410	440
02-23-98	10:42	FC-6g	750	600	91	120
02-23-98	10:45	FC-6h	83000	59000	6000	580
02-23-98		FC-6i	no sample taken			
02-23-98	10:35	MR10	430	120	118	54
02-23-98	11:15	FC-11a	2900	370	290	280
02-23-98	11:00	FC-11c	3800	260	200	400
02-23-98	10:52	FC-11d	370	100	82	60
02-23-98		FC-11e	no sample taken			
02-23-98	11:25	MR11	7600	6300	4000	2500
06-23-98	14:55	MR6	7300	4000	2900	
06-23-98	15:02	FC-6b	34000	2400	1364	
06-23-98	14:47	FC-6c	8600	700	490	
06-23-98	14:45	MR66	87000	42000	26000	
06-23-98	14:43	FC-6e	84000	54000	29000	
06-23-98	14:31	FC-6f	2300	270	250	
06-23-98	15:03	FC-6g	6600	600	227	
06-23-98	14:40	FC-6h	50000	3900	2800	
06-23-98	14:58	FC-6i	8000	800	390	
06-23-98	14:45	MR10	42000	3000	2100	
06-23-98	15:15	FC-11a	65000	4500	2900	
06-23-98	15:00	FC-11c	45000	5000	4600	
06-23-98	14:50	FC-11d	59000	3800	3700	
06-23-98	15:50	FC-11e	69000	2800	2500	
06-23-98	15:30	MR11	73000	2900	2600	

Appendix D.

TMDL Water Quality Monitoring Data, 1999

Sample Collection and Analysis By

Biological Systems Engineering (BSE) Department, Virginia Tech

TMDL Water Quality Monitoring Data, 1999

				<----Water Column Data----->			<--------------Channel Cross-sectional Data --------------->						<-----------Sediment------------->		
No	**Date**	**SiteCode**	**Set No**	**Total Coliform**	**Fecal Coliform**	***E. coli***	**Channel X-section**	**Average Flow**	**Average velocity**	**Width**	**Average Depth**	**Inflow**	**Sediment Weight**	**FC density**	**Fecal Coliform**
				----------- (cfu/100 mL) ---------			(sq.ft.)	(cfs)	(ft/sec)	(feet)	(feet)	(cfs)	(gm/10 mL)	(cfu/gram)	(cfu/100mL)
1	05/04/99	MR 11	26	300	82	63	36.04	15.80	0.438	42	0.86	0.00			43400
2	05/04/99	MR 10	26	2600	96	72	13.08	22.23	1.699	30	0.44	0.26	14.8	25.0	3700
3	05/04/99	MR 9	26	490	57	27	5.41	0.00	0.000	7	0.77	0.00	11.2	226.8	25400
4	05/04/99	MR 8	26	5100	200	117	32.38	7.12	0.220	22	1.47	0.48			1100
5	05/04/99	MR 6	26	7200	41	36	0.00	0.00		0		19.22	12.6	69.8	8800
6	05/11/99	MR 11f	27	546	2	0	0.20	0.17	0.820	0		0.00	17.4	19.5	3400
7	05/11/99	MR 6h	27	1273	0	0	0.15	0.03	0.200	0		0.00	10.4	678.8	70600
8	05/11/99	MR 6b	27	2500	70	0	0.45	0.32	0.700	0		0.00	14.4	305.6	44000
9	05/11/99	MR 5	27	1000	0	0	23.16	19.06	0.823	34	0.68	0.00	16.0	187.5	30000
10	05/11/99	MR 2	27	273	3	0	2.53	0.26	0.103	0		0.17	11.3	161.1	18200
11	06/03/99	MR 11f	28	2500	13	0	0.26	0.04	0.167	5	0.05	0.00	13.4	4.5	600
12	06/03/99	MR 11	28	300	27	18	39.12	4.54	0.116	32	1.22	5.52	17.9	100.0	17900
13	06/03/99	MR 10	28	270	0	0	3.88	5.52	1.422	15	0.26	0.00	17.3	32.4	5600
14	06/03/99	MR 9	28	2500	210	91	3.49	0.00	0.000	8	0.44	0.00	17.4	128.7	22400
15	06/03/99	MR 8	28	3200	25	0	34.20	6.16	0.180	25	1.37	1.34	15.7	13.4	2100
16	06/03/99	MR 6	28	909	0	0	1.38	1.34	0.967	7	0.20	0.22	18.3	93.4	17100
17	06/03/99	MR 6h	28	727	110	0	0.00	0.00		0		2.04	11.5	10.4	1200
18	06/03/99	MR 6b	28	9400	2200	1546	0.00	0.00		0		0	10.3	195.1	20100
19	06/03/99	MR 5	28	320	0	0	13.32	1.78	0.134	27	0.49	0.22	16.0	16.3	2600
20	06/03/99	MR 2	28	780	150	55	0.67	0.22	0.331	3	0.22	0.00	10.0	21.0	2100
21	07/06/99	MR 11f	29	4700	62	36	0.22	0.04	0.180	2	0.11	0.00	17.1	1076.0	184000
22	07/06/99	MR 11	29	5000	52	18	10.02	1.18	0.118	24	0.42	5.41	18.0	1066.7	192000
23	07/06/99	MR 10	29	5400	30	9	3.86	5.41	1.402	13	0.30	0.00	17.6	146.6	25800
24	07/06/99	MR 8	29	840	110	73	29.90	4.58	0.153	21	1.42	0.00	17.1	631.6	108000
25	07/06/99	MR 6	29	2900	790	118	0.00	0.00		0		0.01			
26	07/06/99	MR 5	29	390	200	27	11.90	0.48	0.041	20	0.60	0.01	11.1	164.0	18200
27	07/06/99	MR 2	29	890	680	18	0.10	0.01	0.100	1.5	0.07	0.00	10.7	2616.8	280000

				<----Water Column Data----->			<----------------Channel Cross-sectional Data --------------- >						<-----------Sediment------------->		
No	**Date**	**SiteCode**	**Set No**	**Total Coliform**	**Fecal Coliform**	***E. coli***	**Channel X-section**	**Average Flow**	**Average velocity**	**Width**	**Average Depth**	**Inflow**	**Sediment Weight**	**FC density**	**Fecal Coliform**
				---------- (cfu/100 mL) ----------			(sq.ft.)	(cfs)	(ft/sec)	(feet)	(feet)	(cfs)	(gm/10 mL)	(cfu/gram)	(cfu/100mL)
28	08/03/99	MR 11f	30	7000	114	91	0.26	0.02	0.088	2	0.13	0.00	14.8	582.1	86148
29	08/03/99	MR 11	30	5000	0	0	8.08	2.19	0.270	24	0.34	4.64	18.6	372.0	69186
30	08/03/99	MR 10	30	2500	42	27	8.72	4.64	0.533	16	0.55	0.00	17.6	110.7	19476
31	08/03/99	MR 9	30	8000	128	91	0.00	0.00		0		0.00	14.2	93.3	13242
32	08/03/99	MR 8	30	6700	146	118	6.29	4.91	0.782	20	0.31	0.03	16.7	1104.0	184367
33	08/03/99	MR 6b	30	36000	2000	818	0.00	0.00		0		0.00	16.3	73.4	11963
34	08/03/99	MR 6	30	4800	390	100	0.08	0.03	0.411	1.5	0.05	0.11	15.8	116.2	18358
35	08/03/99	MR 5	30	2100	120	82	0.00	0.00		0		0.11	13.8	486.5	67138
36	08/03/99	MR 2	30	7600	430	270	0.18	0.11	0.620	2	0.09	0.00	12.3	2212.4	272123
37	09/06/99	MR 11f	31	49000	590	500	0.12	0.12	0.986	1.8	0.07	0.00			
38	09/06/99	MR 11	31	40000	790	600	35.38	66.02	1.866	32	1.11	34.33			
39	09/06/99	MR 10	31	8100	250	240	31.80	34.33	1.080	29	1.10	0.00			
40	09/06/99	MR 9	31	30000	590	500	0.00	0.00		0	0.00	0.00			
41	09/06/99	MR 8	31	50000	4200	1091	0.00	0.00		25	0.00	0.67			
42	09/06/99	MR 6b	31	27000	600	182	0.08	0.05	0.665	1.5	0.05	0.00			
43	09/06/99	MR 6	31	260000	43000	16364	0.39	0.62	1.593	3	0.13	0.86			
44	09/06/99	MR 5	31	7800	450	210	12.90	7.79	0.604	22	0.59	0.86			
45	09/06/99	MR 2	31	200000	2900	1818	1.18	0.86	0.730	0	0.00	0.00			

Appendix E.

Matches for Individual DNA Isolates

Sample Collection By
Biological Systems Engineering (BSE) Department, Virginia Tech

Data Analysis By
Biology Department, Virginia Tech

Matches for Individual DNA Isolates

Collection Date	Isolate#	Sample#	Conditions	Match#	%Match	---- No. of Bands ---- Matched	Compared
06/23/98	1	11e-1	ambient	mallard6	80	24	30
06/23/98	1	11e-1	ambient	otter6	86	24	28
06/23/98	1	11e-1	ambient	dog15	80	24	30
06/23/98	2	11e-2	ambient	goose45	97	30	31
06/23/98	3	11e-3	ambient	racc59	81	22	27
06/23/98	3	11e-3	ambient	mallard11	85	22	26
06/23/98	4	11e-4	ambient	musk8	83	24	29
06/23/98	4	11e-4	ambient	musk19	80	20	25
06/23/98	4	11e-4	ambient	der31	86	24	28
06/23/98	4	11e-4	ambient	dog25	86	24	28
06/23/98	5	11e-5	ambient	none	80		
06/23/98	6	11-1	ambient	none	80		
06/23/98	7	11-2	ambient	none	80		
06/23/98	8	11-3	ambient	blackdk	80	24	30
06/23/98	8	11-3	ambient	musk17	80	24	30
06/23/98	8	11-3	ambient	deer6	90	28	31
06/23/98	8	11-3	ambient	dog42	80	24	30
06/23/98	9	11-4	ambient	none	80		
06/23/98	10	11-5	ambient	dog39	82	18	22
06/23/98	10	11-5	ambient	tern5	81	22	27
06/23/98	10	11-5	ambient	goose38	80	20	25
06/23/98	10	11-5	ambient	goose41	80	20	25
06/23/98	11	11-6	ambient	otter84	84	26	31
06/23/98	11	11-6	ambient	racc66	84	26	31
06/23/98	11	11-6	ambient	dog42	93	26	28
06/23/98	11	11-6	ambient	deer6	90	26	29
06/23/98	11	11-6	ambient	dog41	93	26	28
06/23/98	12	11-7	ambient	goose29	80	24	30
06/23/98	13	11-8	ambient	hum42	80	24	30
06/23/98	13	11-8	ambient	dog25	84	26	31
06/23/98	13	11-8	ambient	deer35	81	26	32
06/23/98	13	11-8	ambient	racc62	81	26	32
06/23/98	13	11-8	ambient	dog4	81	26	32
06/23/98	14	6h-1	ambient	dog18	81		
06/23/98	15	6h-2	ambient	racc14	80	24	30
06/23/98	16	6h-3	ambient	ydog7	88	22	25
06/23/98	16	6h-3	ambient	hum42	81	22	27
06/23/98	16	6h-3	ambient	mallard11	81	22	27
06/23/98	16	6h-3	ambient	ycow1	81	22	27
06/23/98	17	6h-4	ambient	hum22	83	24	29
06/23/98	17	6h-4	ambient	deer3	86	24	28
06/23/98	17	6h-4	ambient	deer6	80	24	30
06/23/98	18	6h-5	ambient	none	80		
06/23/98	19	6h-6	ambient	deer6	81	26	32
06/23/98	19	6h-6	ambient	racc62	85	28	33

Collection Date	Isolate#	Sample#	Conditions	Match#	%Match	---- No. of Bands ---- Matched	Compared
06/23/98	20	6h-7	ambient	ycow14	83	24	29
06/23/98	20	6h-7	ambient	hum42	86	24	28
06/23/98	21	6b-1	ambient	mallard7	84	26	31
06/23/98	21	6b-1	ambient	ydog3	87	26	30
06/23/98	21	6b-1	ambient	hum51	85	28	33
06/23/98	21	6b-1	ambient	tern7	85	28	33
06/23/98	22	6b-2	ambient	racc3	80	24	30
06/23/98	23	6b-3	ambient	musk13	80	28	35
06/23/98	23	6b-3	ambient	dog33	80	24	30
06/23/98	23	6b-3	ambient	dog25	81	26	32
06/23/98	23	6b-3	ambient	ycow19	82	28	34
06/23/98	23	6b-3	ambient	teal1	80	24	30
06/23/98	23	6b-3	ambient	hum5	83	30	36
06/23/98	24	6b-4	ambient	dog19	80	24	30
06/23/98	25	6b-5	ambient	none	80		
06/23/98	26	6b-6	ambient	none	80		
06/23/98	27	6b-7	ambient	none	80		
07/22/99	1	2-1a	runoff	hum21	82	28	34
07/22/99	1	2-1a	runoff	yhorse	82	28	34
07/22/99	2	2-1b	runoff	otter10	80	24	30
07/22/99	2	2-1b	runoff	yhorse2	81	26	32
06/02/99	3	2-2	runoff	none	80		
06/02/99	4	6-1	ambient	none	80		
06/02/99	5	6-2	ambient	dog12	87	26	30
06/02/99	5	6-2	ambient	dog26	80	24	30
06/02/99	5	6-2	ambient	ydog8	85	28	33
06/02/99	5	6-2	ambient	yhorse1	81	26	32
06/02/99	5	6-2	ambient	yhorse1	81	26	32
06/02/99	6	8-1	ambient	ycow13	80	24	30
06/02/99	7	8-2	ambient	musk19	85	22	26
06/02/99	8	9-1	ambient	none			
06/02/99	9	11f-1	ambient	none			
09/06/99	10	5-1	runoff	wooddk2	89	24	27
09/06/99	10	5-1	runoff	hum20	83	24	29
09/06/99	11	5-2	runoff	none			
09/06/99	12	5-3	runoff	ycow10	85	28	33
09/06/99	12	5-3	runoff	dog8	80	24	30
09/06/99	12	5-3	runoff	ycow9	81	26	32
09/06/99	13	5-4	runoff	none			
09/06/99	14	5-5	runoff	rac42	87	26	30
09/06/99	14	5-5	runoff	ycow4	82	28	34
09/06/99	14	5-5	runoff	dog36	82	28	34
09/06/99	14	5-5	runoff	rac11	82	28	34
09/06/99	15	6-1	runoff	human35	80	24	30
09/06/99	15	6-1	runoff	blackduck	82	22	27
09/06/99	16	6-2	runoff	ydog8	82	28	34
09/06/99	16	6-2	runoff	mallard4	83	24	29
09/06/99	16	6-2	runoff	goose27	87	26	30

Collection Date	Isolate#	Sample#	Conditions	Match#	%Match	---- No. of Bands ---- Matched	Compared
09/06/99	16	6-2	runoff	human62	82	28	34
09/06/99	17	6-3	runoff	dog3	85	22	26
09/06/99	18	6-4	runoff	wooddk3	80	24	30
09/06/99	18	6-4	runoff	mallard8	80	24	30
09/06/99	18	6-4	runoff	yhorse8	81	26	32
09/06/99	19	6-5	runoff	goose43	80	20	25
09/06/99	19	6-5	runoff	goose36	86	24	28
09/06/99	20	6-6	runoff	blackdk1	81	22	27
09/06/99	20	6-6	runoff	blackdk10	86	24	28
09/06/99	20	6-6	runoff	mallard1	86	24	28
09/06/99	21	6-7	runoff	musk24	85	22	26
09/06/99	21	6-7	runoff	dog7	81	22	27
09/06/99	22	6-8	runoff	mallard8	83	24	29
09/06/99	22	6-8	runoff	mallard7	86	24	28
09/06/99	22	6-8	runoff	goose31	81	22	27
09/06/99	23	8-1	runoff	musk28	80	20	25
09/06/99	23	8-1	runoff	dog31	81	22	27
09/06/99	23	8-1	runoff	dog2	81	26	32
09/06/99	24	8-2	runoff	drac	82	28	34
09/06/99	25	8-3	runoff	none	80		
09/06/99	26	8-4	runoff	none	80		
09/06/99	27	8-5	runoff	otter14	85	28	33
09/06/99	27	8-5	runoff	dog2	83	30	36
09/06/99	28	8-6	runoff	none	80		
09/06/99	29	8-7	runoff	blackdk	81	22	27
09/06/99	30	8-8	runoff	none	80		
09/06/99	31	9-1a	runoff	none	80		
09/06/99	32	9-1b	runoff	none	80		
09/06/99	33	9-2	runoff	none	80		
09/06/99	34	9-3	runoff	none	80		
09/06/99	35	9-4	runoff	ybeav1	80	24	30
09/06/99	36	9-5	runoff	musk19	80	20	25
09/06/99	37	10-1	runoff	ycow20	83	24	29
09/06/99	38	10-2	runoff	musk22	82	28	34
09/06/99	38	10-2	runoff	hum19	85	28	33
09/06/99	38	10-2	runoff	hum38	81	26	32
09/06/99	38	10-2	runoff	musk12	81	26	32
09/06/99	39	10-3	runoff	none	80		
09/06/99	40	10-4	runoff	tern4&5	82		
09/06/99	40	10-4	runoff	goose27	86	24	28
09/06/99	40	10-4	runoff	ybeav1	86	24	28
09/06/99	41	10-5	runoff	none	80		
09/06/99	42	10-6	runoff	yhorse	84	26	31
09/06/99	42	10-6	runoff	ycow13&14	87	26	30
09/06/99	42	10-6	runoff	tern7	84	26	31
09/06/99	42	10-6	runoff	musk22	88	28	32
09/06/99	43	10-7	runoff	ydog7	83	20	24
09/06/99	44	11-1	runoff	hum22	83	24	29

Collection Date	Isolate#	Sample#	Conditions	Match#	%Match	---- No. of Bands ---- Matched	Compared
09/06/99	44	11-1	runoff	hum42	83	24	29
09/06/99	44	11-1	runoff	dog27	84	26	31
09/06/99	44	11-1	runoff	dog11	84	26	31
09/06/99	44	11-1	runoff	dog17	84	26	31
09/06/99	45	11-2	runoff	hum53	81	22	27
09/06/99	46	11-3	runoff	hum27	80	28	35
09/06/99	46	11-3	runoff	hum24	82	28	34
09/06/99	47	11-4	runoff	none	80		
09/06/99	48	11-5	runoff	dog8	83	24	29
09/06/99	48	11-5	runoff	hum48	81	26	32
09/06/99	49	11f-1	runoff	none	80		
09/06/99	50	11f-2	runoff	hum41	80	20	25
09/06/99	50	11f-2	runoff	deer6	86	24	28
09/06/99	51	11f-3	runoff	ybeav1	83	24	29
09/06/99	52	11f-4	runoff	otter14	80	24	30
09/06/99	52	11f-4	runoff	racc10	80	24	30
09/06/99	52	11f-4	runoff	musk33	80	24	30
09/06/99	52	11f-4	runoff	otter12	80	24	30

Appendix F.

Unknown Stream Sample DNA Matches with Virginia Tech DNA Library

Sample Collection By
Biological Systems Engineering (BSE) Department, Virginia Tech

Data Analysis By
Biology Department, Virginia Tech

Unknown Stream Sample DNA Matches with Virginia Tech DNA Library

Sampling Site	Sample Strain	Matching Categories of Known Samples	Sampling Site	Sample Strain	Matching Categories of Known Samples
2	1a	***horse***, human	11	1	dog, human
	1b	***horse***, otter		2	human
	2	NONE		3	human
6	1	NONE		4	NONE
	2	***horse, dog***		5	dog, human
8	1	***cow***	11f	1	NONE
	2	muskrat		2	deer, human
9	1	NONE		3	***beaver***
11f	1	NONE		4	muskrat, otter, raccoon
5	1	wood duck, human	11e	1	dog, otter, mallard
	2	none		2	goose
	3	dog, ***cow***		3	raccoon
	4	NONE		4	deer, dog, muskrat
	5	dog, raccoon, ***cow***		5	NONE
6	1	black duck, human	11	1	goose
	2	***dog***, goose, mallard, human		2	NONE
	3	dog		3	deer, dog, black duck, muskrat
	4	***horse***, mallard, wood duck		4	NONE
	5	goose, mallard, black duck		5	goose, dog, tern
	6	black duck		6	deer, dog, otter, raccoon
	7	dog, muskrat		7	goose
	8	goose, mallard		8	dog, human, raccoon
8	1	muskrat, dog	6h	1	dog
	2	raccoon		2	raccoon
	3	NONE		3	***dog, cow***, mallard, human
	4	NONE		4	deer, human
	5	dog, otter		5	NONE
	6	NONE		6	deer, raccoon
	7	black duck		7	***cow***, human
	8	NONE	6b	1	***dog***, mallard, human, tern
9	1	NONE		2	raccoon
	2	NONE		3	***cow***, dog, teal, human, muskrat
	3	NONE		4	dog
	4	***beaver***		5	NONE
	5	muskrat		6	NONE
10	1	***cow***		7	NONE
	2	human, muskrat			
	3	NONE			
	4	***beaver***, goose, tern			
	5	NONE			
	6	***horse***, muskrat, tern, ***cow***			
	7	***dog***			

Sample categories in ***bold, italicized*** type are matches with “known” samples from this study.

Appendix G.

Fecal Coliform Counts and Densities in Animal Waste

Data Collection and Analysis By

Biological Systems Engineering (BSE) Department, Virginia Tech

Fecal Coliform Counts and Densities in Animal Waste[1]

Date	SampleNo	Animal Type	Location	Total Coliform	Fecal Coliform	*E. Coli*	FC Density	Flag
				-------- (cfu / 20 grams) --------			(cfu/gram)	
04/20/99	1	dairy	storage	500000	500000	500000	25,000	
04/20/99	2	dairy	fresh	>1600000	1600000	1600000	80,000	
04/20/99	3	dairy	spread	50000	50000	50000	2,500	
04/20/99	4	dairy	pasture	70000	70000	70000	3,500	
04/20/99	5	heifers	fresh	>160000	160000	160000	8,000	
04/20/99	6	horse	fresh	4000	<2000	<2000	100	<
04/20/99	7	horse	fresh	>1600000	<2000	<2000	100	<
04/20/99	8	beef	fresh	160000	90000	90000	4,500	
04/20/99	9	heifer	feedlot	>1600000	>1600000	>1600000	80,000	>
04/20/99	10	heifer	storage	>160000	>160000	>160000	8,000	>
04/20/99	11	dairy	pasture	>160000	>160000	>160000	8,000	>
04/20/99	12	beef	spread	8000	8000	8000	400	
04/27/99	13	beef	pasture	>1600000	>1600000	>1600000	80,000	>
04/27/99	14	swine	storage	>1600000	>1600000	>1600000	80,000	>
04/27/99	15	swine	fresh	>1600000	>1600000	>1600000	80,000	>
04/27/99	16	beef	spread	23000	23000	23000	1,150	
04/27/99	17	beef	pasture	>1600000	>1600000	>1600000	80,000	>
04/27/99	18	young beef	feedlot	>1600000	>1600000	>1600000	80,000	>
04/27/99	19	dairy	spread	70000	<2000	<2000	100	<
04/27/99	20	dairy	storage	>1600000	>1600000	>1600000	80,000	>
05/04/99	21	dairy	spread	<20	<20	<20	1	<
05/11/99	22	beef	spread	17000	17000	17000	850	
05/11/99	23	dairy	spread	200	<200	<200	10	<
05/18/99	24	dairy	pasture	900	900	900	45	
05/18/99	25	beef	pasture	14000	14000	14000	700	
05/18/99	26	beef	pasture	16000	16000	16000	800	
05/18/99	27	goose	fresh	16000000	16000000	16000000	800,000	
05/18/99	28	deer	fresh	9000000	9000000	9000000	450,000	
05/18/99	29	muskrat	fresh	5000000	5000000	5000000	250,000	
05/18/99	30	raccoon	fresh	5000000	5000000	5000000	250,000	
05/18/99	31	dairy	pasture	5000	5000	5000	250	
05/18/99	32	dairy	spread	90000	90000	90000	4,500	
06/16/99	33	dairy	pasture	90000	90000	90000	4,500	
06/16/99	34	horse	fresh	500000	500000	500000	25,000	
06/16/99	35	horse	fresh	22000	8000	8000	400	
06/16/99	36	beef	pasture	160000	160000	160000	8,000	
06/16/99	37	beef	pasture	90000	90000	90000	4,500	
06/16/99	38	dog	fresh	900000	900000	900000	45,000	
06/16/99	39	beaver	fresh	<20000	<20000	<20000	1,000	<
06/16/99	40	dairy	pasture	16000	16000	16000	800	
06/22/99	41	young beef	feedlot	90000	90000	90000	4,500	
06/22/99	42	heifer	feedlot	500000	500000	500000	25,000	

Date	SampleNo	Animal Type	Location	Total Coliform	Fecal Coliform	*E. Coli*	FC Density (cfu/gram)	Flag
				-------- (cfu / 20 grams) --------				
06/22/99	43	bio-solid	fresh	<20	<20	<20	1	<
08/31/99	44	dairy	storage	23000	23000	13000	1,150	
08/31/99	45	dairy	pasture	>1600000	>1600000	1600000	80,000	>
08/31/99	46	dairy	storage	<2000	<2000	<2000	100	<
08/31/99	47	swine	storage	50000	50000	50000	2,500	
08/31/99	48	beef	pasture	14000	14000	14000	700	
08/31/99	49	young beef	feedlot	>1600000	>1600000	>1600000	80,000	>
08/31/99	50	beef	pasture	<2000	<2000	<2000	100	<
08/31/99	51	heifer	storage	220000	220000	220000	11,000	
08/31/99	52	dairy	pasture	>1600000	>1600000	1600000	80,000	>
08/31/99	53	dairy	feedlot	>1600000	>1600000	>1600000	80,000	>
10/27/99	54	dairy	fresh	>16000000	>16000000	>16000000	800,000	>
10/27/99	55	beef	fresh	>160000000	>160000000	>160000000	8,000,000	>
10/27/99	56	dairy	fresh	>160000	160000	160000	8,000	
10/27/99	57	heifer	fresh	34000	34000	34000	1,700	
10/27/99	58	beef	fresh	1700	1700	1700	85	
10/27/99	59	swine	fresh	80000	20000	20000	1,000	
10/27/99	60	beef	fresh	2100	1300	1300	65	
10/27/99	61	dairy	fresh	>160000000	>160000000	>160000000	8,000,000	>
10/27/99	62	heifer	fresh	16000000	80000	80000	4,000	

[1] Animal waste analysis in the Mt. Run project was carried out using the Most Probable Number (MPN) method. The MPN procedure estimates the number of specific organisms by the use of probability tables. Decimal dilutions of samples are inoculated in series into liquid tube media. Growth and/or fermentative gas production indicate positive tests. Bacterial densities are based on combinations of positive and negative tube results read from the MPN tables. At this time, the MPN method is the best-suited procedure for the examination of mud, sludge, sediment, and manure because particulates do not interfere visibly with the test. The MPN method is limited however by several factors: 1) Fecal Coliform, and E. coli are not analyzed independently; that is Fecal Coliform and E. coli are analyzed only if the Total Coliform tube is positive at the presumptive test. If all tubes tested are positive through the confirmed test then the count calculated from the MPN table would have the same result. 2) The MPN tables are probability calculations and inherently have poor precision.

Appendix H.

Whole Farm Fecal Coliform Load Calculator

Fortran Routine Written By
Gene Yagow, BSE Dept., Virginia Tech

Whole Farm Fecal Coliform Load Calculator

```
$debug
$storage:2
c  PERLND FC Load Calculator ( prl-fcr.for )
c
c  Based on number and type of animals per farm
c  Based on the time animals spend on various land use types
c  Based on four agricultural land uses: cropland(spreading
c       areas), pasture, loafing areas, and stream access areas
c
c    Written by Gene Yagow  03/15/00
c    Modified from wf-fcr.for for input to HSPF
c    3/15 corrected hrsll array
c ----------------------------------------------------------------
      integer frm,lu,nn(0:200),mm(0:200),hrssn(4)
      integer site,farm,antyp,annum,avwgt,hrsll(4,4),lucat
      real dpr(4),dk,pop(4),pctcol(4),sp,pa,ll,sn
      real area,spac(200),paac(200),llac(200),snac(200),sp1,sp2
      real anfc,llm,snm,pam,llfc(200),pafc(200),spm
      real spfc(200,4),snfc(200)
      integer hrsl,hrss,farmno,perlnd,luc(0:200),jj(4000),kk(4000)
      real prst(200,4),prsn(200,4)
      real fc,pctprl,acre,prfc(200,4)
      character*50 awdata,prldat,wfout
c  Hardwire data for Daily FC Production Rates and Manure FC
c  Density by Animal Type.
c  Animal Type: 1=beef; 2=dairy; 3=swine; 4=horse
c ---- based on an average of all measured beef,dairy and heifer
c ---- manure sample densities (1,143,000) and ASAE 1996 daily
c ---- manure production w/o urine (units: FC * 10^9/AU/day)
      data dpr/20.74,31.11,67.36,0.234/
      data pop/1.00,1.04,1.06,1.00/
      data hrssn/0,1,2,4/
      data pctcol/0.60,0.80,0.95,1.00/
c     data hrsll/24,24,10,24,8,12,10,24,4,6,10,24,0,4,10,24/
      data hrsll/24,24,24,10,8,12,24,10,4,6,24,10,0,4,24,10/
c  DK is the percent die-off in storage
c   based on the fresh density of 1,143,000 and the average of
c   all manure samples (25,969)
      data dk/0.9773/
c -----------------------------------------------------------------

c  Read the response file
      open(20,file='prl-fcr.rsp')
      read(20,'(a50)')awdata,prldat,wfout
      close(20)

c  Calculate Daily FC Loads By Perland for each Seasonal Quarter
c  Qtr1 = Dec-Feb; Qtr2 = Mar,Nov; Qtr3 = Apr-May,Sep-Oct; Qtr4 = Jun=-Aug
c ---- n = Seasonal quarter counter
      do 500 n = 1,4

c  Initialize all field area matrix values to 0.0
         do 10 i=1,200
            llfc(i) = 0.0
```

```
            pafc(i) = 0.0
            spfc(i,n) = 0.0
            snfc(i) = 0.0
10       continue

c  Calculate daily distribution of FC to each of 4 land types by farm
         i = 0
         nn(i) = 0

c  Open the livestock data file for your watershed and read in
c  and process one line at a time. (mo-wffc.txt)
c  Disregard LU = 0 or 6
         open(21,file=awdata)
         open(22,file='farmfc.sum')
         write(22,*)'       farm     antype        anfc'
c ---- sorted by FARM
         read(21,210)
40       read(21,*,end=50)site,farm,antyp,annum,avwgt,snav,llav
c -------------------- i = FARM counter
            if(farm.ne.nn(i)) i = i + 1
            nn(i) = farm
            jj(farm) = i
            if(antyp.eq.1.or.antyp.eq.2.or.antyp.eq.13) antyp = 1
            if(antyp.eq.3.or.antyp.eq.4) antyp = 2
            if(antyp.eq.5.or.antyp.eq.6) antyp = 3
            if(antyp.eq.11) antyp = 4
c ---- snav = 1 (stream acces available); snav = 0 (no stream access)
c ---- llav > 0 (confined area available); llav = 0 (no confined area)
            do 42 k=1,i
               if(farm.eq.nn(k)) go to 44
42          continue
            if(k.eq.i.and.farm.ne.nn(k)) go to 40
44          continue
c  Calculate total manure by animal type for each farm
c    output units are FC*10^9/day

            anfc = annum * avwgt * dpr(antyp) / 1000.
c ---- account for seasonally-variable population of beef
            if(antyp.eq.1) anfc = anfc * pop(n)
c ---- calculate loafing lot daily FC load * 10^9
            if(llav.gt.0) then
               llm = (real(hrsll(antyp,n))/24.) * anfc *
     #            (1-pctcol(antyp))
               hrsl = hrsll(antyp,n)
            else
               llm = 0.
               hrsl = 0
            endif
c ---- calculate stream access area daily FC load * 10^9
            if(snav.eq.1) then
               if((hrsl+hrssn(n)).ge.24) THEN
                  hrss = 24 - hrsl
               else
                  hrss = hrssn(n)
               endif
               snm = real(hrss)/24. * anfc
            else
```

```
            snm = 0.0
            hrss = 0
         endif
c ---- calculate pasture area daily FC load * 10^9
         pam = anfc * (1.-real(hrsl+hrss)/24.)
c ---- calculate manure stored for eventual cropland application * 10^9
         spm = pctcol(antyp) * (real(hrsl)/24) * anfc
c ---- update farm totals by manure category
         llfc(i) = llfc(i) + llm
         snfc(i) = snfc(i) + snm
         pafc(i) = pafc(i) + pam
         spfc(i,n) = spfc(i,n) + spm
         write(22,*)farm,antyp,anfc
      go to 40
50    continue
      close(21)

c ---- Write FC Loads * 10^9 by Farm and Land Type
      write(22,*)' Farm Summary: Animal Type = ',antyp
      write(22,*)'    units = FC * 10^9/day'
      write(22,*)'  FarmNo   StorageFC   PastureFC   LoafLotFC   Strea
     #mFC'
      do 60, m=1,i
         write(22,600) nn(m),spfc(m,n),pafc(m),llfc(m),snfc(m)
60    continue

      do 70 m=1,200
         prst(m,n) = 0
         prfc(m,n) = 0
         prsn(m,n) = 0
70    continue

c ---- Assign each Farm/Land Type FC Amount to a Specific PERLND
      open(21,file=prldat)
      j = 0
      mm(j) = 0

      read(21,210)
c ---- sorted by PERLND, then FARMNO
      write(22,*)' PRL LU FARM     STFC    PAFC    LLFC   SNFC   PRLFC
     #      STORAGE   STREAM'
100   read(21,*,end=400)farmno,perlnd,lucat,pctprl,acre
c ---------------------- j = PERLND counter
         if(perlnd.ne.mm(j)) j = j + 1
         mm(j) = perlnd
         luc(j) = lucat

c ---- do loop to ensure singular sums for each PERLND
         do 90 k = 1,i
            if(farmno.eq.nn(k)) go to 95
90       continue
         go to 100
95       do 110 k = 1,j
            if(perlnd.eq.mm(k)) go to 120
110      continue
         if(k.eq.j.and.perlnd.ne.mm(k)) go to 100
120      continue
```

```
            sp = 0
            pa = 0
            ll = 0
            sn = 0

            if(luc(j).eq.100) then
               sp = spfc(jj(farmno),n) * pctprl
               prst(j,n) = prst(j,n) + sp
            elseif(luc(j).eq.200) then
               pa = pafc(jj(farmno)) * pctprl
               prfc(j,n) = prfc(j,n) + pa
            elseif(luc(j).eq.300) then
               ll = llfc(jj(farmno)) * pctprl
               prfc(j,n) = prfc(j,n) + ll
            elseif(luc(j).eq.400) then
               sn = snfc(jj(farmno)) * pctprl
               prsn(j,n) = prsn(j,n) + sn
            endif
         write(22,380)perlnd,lucat,farmno,sp,pa,ll,sn,
     #      prfc(j,n),prst(j,n),prsn(j,n)
         go to 100
400      continue

500   continue
      close(21)

      open(21, file=wfout)
      write(21,*)' PERLND Summary: Animal Type = ',antyp
      write(21,*)'     units = FC * 10^9/day'
      do 550 i = 1,j
         if(luc(i).eq.100) then
            prfc(i,1) = 0
c ---- prfc = (30 days/mo * sum (no. of mo./qtr * daily storage/qtr))
c             divided by (30 days in the month if spreading) * (1 - dk)
c ---- April application load
            prfc(i,2) = (3*prst(i,1)+2*prst(i,2)+prst(i,3)) *
     #                  (1.0 - dk)
            prfc(i,3) = 0
c ---- October application load
            prfc(i,4) = (3*prst(i,3)+3*prst(i,4)) * (1.0 - dk)
         endif
         write(21,600)mm(i),(prfc(i,k),k=1,4),(prsn(i,k),k=1,4)
550   continue
      close(22)
      close(21)
210   format()
380   format(i3,i4,i5,4f9.1,3f9.1)
600   format(i10,',',7(f12.1,','),f12.1)

      end
```

Appendix I.

Responses to EPA Comments of April 2000

Responses to EPA Comments of April 2000

1. **Page xi, Existing Conditions, During what flow conditions do straight pipes and cattle in-stream most affect higher concentrations?** The revised report will be rephrased to read: "Of the two major influences on the 30-day geometric mean, one was a direct nonpoint source – "cows-in-streams" – which would dominate during low flow conditions, and the other was washoff from impervious areas, which would dominate during high flow conditions."

2. **Page xi, TMDL, The Margin of Safety is not meant to account for future growth.** The revised report will be rephrased to read: "To account for uncertainties in the modeling, a margin of safety was included by developing the TMDL allocations based on a target that was 5% lower than the standard. The TMDL was developed to account for future population growth and accompanying land use changes."

3. **Page xiii, Public Participation, The three public meetings that were held were based on State not EPA requirements.** The revised report will be rephrased to read: "Finally, in compliance with the EPA requirement for public participation, three public meetings were organized and conducted by the state as part of the formalized TMDL process."

4. **Page 1, Section 1.1, An explanation of Waste Load Allocation (WLA) and Load Allocation (LA) should be incorporated into this section. Mountain Run was identified on the 303(d) list for a benthic impairment as well.** The revised report will be rephrased and supplemented to read: "Section 303(d) of the Federal Clean Water Act and the U.S. Environmental Protection Agency's (USEPA) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to identify waterbodies that violate state water quality standards and to develop Total Daily Maximum Loads (TMDLs) for such waterbodies. A TMDL is defined as follows for any given point in time:

$$\text{TMDL} = \text{WLA} + \text{LA} + \text{MOS}$$

where TMDL = the target load or concentration,
WLA = the point source load or concentration,
LA = the non-point source load or concentration, and
MOS = margin of safety.

TMDLs developed to meet a concentration standard are dependent on time-variable flow conditions. A TMDL, therefore, can either be the maximum allowable pollutant load received by, or the maximum concentration of a pollutant measured in, a water body, such that it does not exceed the governing water quality standard or criteria. A TMDL plan quantifies the various sources of the target pollutant, determines the load reductions by source needed to attain the target TMDL load or concentration, and provides a framework for taking actions to restore water quality."

While Mountain Run was also identified on the 1998 303(d) list for a benthic impairment, this TMDL is for the fecal coliform impairment only, explaining why the benthic impairment is not mentioned.

5. **Page 3, Figure 1.2, Please provide a key describing the different color patterns in this map.** The revised report will include a revised Figure 1-2 with a simplified color scheme and a key.

6. **Page 7, Figure 2.1, Were fecal coliform concentrations reported in concentrations below 100 cfu/100 mL?** Yes, fecal coliform was reported in concentrations less than 100 cfu/100 mL. Individual sample fecal coliform measurements are listed by date and monitoring site in Appendix A.

7. **Page 7, Section 2.2.1, Please reword the last sentence and quantify high and low flows.** The revised report will be rephrased to read: "Figure 2-2 shows the distribution of fecal coliform concentrations for both of the DEQ sites and corresponding flow at the upstream USGS gage. A natural break in the data at 27 cfs was used to classify flows as higher or lower. For the upstream site, all reported WQS violations occurred at flows less than 27 cfs. At the outlet site, violations occurred during both low and high flows. Samples taken at the outlet site that corresponded with high flow almost always were in violation of the standard. At lower flows, violations still occurred, but with less frequency, and apparently unrelated to flow conditions. High concentrations during high flow are generally related to pollutant loads transported to streams by surface runoff, while high concentrations during low flow indicate sources contributing directly to the stream itself. Therefore, it is likely that different types of sources and transport mechanisms are operating in the upstream and downstream portions of the watershed. It should also be noted that during low flow, high concentrations can be produced by relatively small loads."

   Figure 2-2 will be revised to include a vertical line showing the natural break.

8. **Page 8, Section 2.2.2, The report mentions that "Neither was the outlet appreciably affected as no monitored violations were recorded by RRPDC…" However, several violations were recorded by DEQ at the outlet. In 1997, both DEQ and RRPDC monitored this site, therefore there were samples taken once every two weeks, can we use the geometric mean standard for this time period as well.** For assessment purposes, DEQ applies either the instantaneous or the geometric mean standard to any given data set. Because more frequent sampling was not available for the whole assessment period, the instantaneous standard was applied to water quality data in Mountain Run. All data were included in developing the model. The following statistics were calculated regarding the fecal coliform measurements taken concurrently by DEQ and RRPDC:

No. of Days in Total Observation Period (Oct. 96 - Dec. 97)	477
No. of Observations Exceeding 1000 WQS	2
Total No. of Observations (DEQ-14; RRPDC-16)	30
% Exceedance 1000 WQS	0.067
No. of Observations Within 30 Days of Each Other	25
No. of Days Included in Geometric Mean Assessment	370
No. of Geometric Mean Calculations Exceeding 200 WQS	9
No. of Included Days (No. of Days Exceeding 200 WQS)	136
% Exceedance 200 WQS: (Days Exceeding/Days Assessed)	0.368
% Exceedance 200 WQS: (Days Exceeding/Total Observation Period)	0.285

9. **Page 10, Section 2.2.3, The statement that violations at station #7 were attributed to higher inputs from subwatershed #6 seems to contradict statements made in Section 2.2.2.** The revised report will be rephrased in Sec. 2.2.2 to read: "The high concentrations at site 6 appeared to be localized during base flow conditions and only affected downstream concentrations during the one sampling where stream levels were elevated from several days of rain prior to sampling."

   The revised report will be rephrased in Sec. 2.2.3 to read: "Station 7 was discontinued as the one violation reported there was attributed to loading from an upstream site (6) that was transported during storm runoff from recent rains."

10. **Page 15, Figure 2-12, In order to more easily extract information from this table please color code each sampling date.** Figure 2-12 will be revised to enable extraction of sample measurements by sampling date. Since the printed document is not in color, different markers will be used, rather than colors to differentiate between the different dates.

11. **Page 17, Section 3.1, Please change the statement that "The Culpeper wastewater treatment plant is the only one of these three…" to the only one of these four.** The revised report will be rephrased to read: "The Culpeper wastewater treatment plant (WWTP) is the only one of these four that is actually discharging into Mountain Run."

12. **Page 18, Section 3.2.2, The report treats all septic tanks greater than 20 yrs old as failures. Please, document why this is being done. How are septic tank systems less than 20 years old treated? Please explain the rational.** The revised report will be rephrased in Sec. 3.2.2 to read: "Properly installed and maintained septic systems are designed to properly treat waste and should not contribute fecal coliform to streams. However, improperly installed or maintained systems, and those rural residences without a septic treatment system, represent potential sources of human fecal coliform within the watershed. The year 1978 (20 years ago at the start of this project) was chosen in consultation with the local Health Department to represent a starting point after which newly installed septic systems would have been built to regulated specifications that represent a proper installation. Septic systems installed prior to this time were less likely to be

permitted and were treated as sources of fecal coliform as detailed in Section 4.4. Of the septic systems in the watershed, 207 were 20 years old or older."

13. **Page 20, Section 3.2.3, Why were raccoon excluded from urban areas?** This was based on best professional judgment at the time. This exclusion was revised after the third public meeting based on feedback from the public and others. However, loading rates from all sources to urban areas was a calibrated parameter and so indirectly incorporated any contributions from raccoons and other sources as well. In other words, raccoon habitat should not have excluded urban areas, but their contribution to those areas is in fact already included in the model. The revised report will be rephrased to read: "raccoon: all areas within 400 meters of perennial streams, excluding loafing lot and pasture areas."

14. **Page 33, Section 4.3.2, The report mentions that 1.39 MGD were withdrawn from Lake Pelham for treatment and distribution and 2.17 MGD were returned to the WWTP. Since it is mentioned that Stormwater does not go to the plant, please explain the differences in these values.** Daily withdrawals and discharge were obtained directly from the Town of Culpeper. The only explanation given by the Town when asked about the difference during the third public meeting was I&I – inflow and infiltration.

15. **Page 35, Section 4.4, Should the permitted fecal coliform concentrations be used during the modeling for each point source?** All permitted discharges of fecal coliform and flow were modeled at their maximum permitted limit for all of the TMDL alternatives. It would not be appropriate to model these under existing conditions, because in fact they are not contributing. Including non-existent contributions under the existing conditions would make them appear to be part of the problem.

16. **Page 38, Table 4.2, What percent of time were cattle with stream access assumed to actually be in the stream?** The hours/day reported for livestock with stream access refer to hours assumed to be in the stream. None of the units in that section refer to percentages. The revised report will be clarified and rephrased so that the first line under the header "Animal Type" in Table 4-2 reads: "stream access (hrs in stream/day)".

17. **Page 38, Table 4-4, Please document how the deposition of fecal coliform to each source was determined.** The revised report will be rephrased to read: "A computer program was written to distribute fecal coliform from livestock on each farm amongst the four livestock manure application categories, and then from each application category to individual pervious land segments (PLS). The program code is listed in Appendix H for reference. A spreadsheet was then used to format the inputs needed for the monthly loading table. Fecal coliform loads from livestock were calculated in the program using the fecal coliform densities in manure and daily manure production per animal listed in Table 4-3, along with seasonally-variable populations of livestock."

18. **Page 46, Figure 4-3,Where are the locations of Lake Caynor and Lake Rillhurst on this figure?** Figure 4-3 will be revised to include Lake Caynor and Rillhurst.

19. **Page 56, Section 5.3, The point sources should be treated as though they are discharging at their permitted limits.** As mentioned previously, adding non-existent loads under the existing conditions makes WWTPs appear to be part of the problem. However, while contributions from various sources were based on existing conditions, reductions in the alternative TMDL scenarios were based on future conditions, not the existing ones. All scenarios based on future conditions incorporate the maximum permitted flow and fecal coliform concentrations.

    The revised report will expand Section 5.3 to read: "Under the future scenario and all TMDL reduction scenarios, this reserved fecal coliform loading was incorporated for each facility as their maximum permitted daily flow rate times the permitted fecal coliform concentration."

    The revised report will also rephrase Section 5.4 to read: "Dominant fecal coliform sources identified in the analysis were then subjected to five different allocation/reduction schemes for meeting the TMDL target, using future conditions as the base against which reductions were made."

20. **Page 56, Table 5.1, Please include the amount of each load.**
    The revised report includes two tables on page 58 to more fully describe the existing load: Table 5-2 quantifies loads applied to the land surface within each sub-watershed by FC source, while Table 5-3 quantifies loads delivered to the stream and loads exiting the outlet from each source.

21. **Page 56, Section 5.5, Please explain why several of the sources with the greatest loading to the stream provide very little of the load during average conditions? Address how storm events are needed to transport land applied wastes to the stream and that these loads are flushed from the stream quickly due to the expanded discharge.**
    The explanation has been moved to Section 5.6 (p. 62-63) to justify the sources chosen for reductions, and will read: "The remaining land-based sources – wildlife, livestock-on-the-land, and urban-pervious – are all deposited on the land surface and only impact stream concentrations when transported to the stream during storm runoff. During runoff events, the larger volumes of water dilute the concentrations and mask the larger loads indicated from Table 5.1. Runoff events are also relatively short in nature, and therefore, have less impact on the geometric mean than somewhat smaller concentrations that contribute more frequently, as from impervious runoff, or continuously, as the in-stream sources. All of the alternative TMDL solutions will produce many events with FC concentrations in excess of the 1000 cfu/100 mL instantaneous standard from agricultural runoff, even though it appears to have an insignificant impact on the geometric mean. In the tables shown previously, the loading from agriculture is significantly larger than all of the other sources. However, reducing it will not significantly reduce the geometric mean concentration because of its entry only during relatively infrequent runoff events, and because of the mathematics of the geometric mean. While impervious loading also occurs

only during runoff events, loading is generated with relatively smaller runoff events making them occur more frequently than from agricultural areas, producing a greater effect on the geometric mean."

22. **Page 64, Tables 5.5 thru 5.7, What is meant by the word "TOWN"?** The word TOWN in Tables 5.5 through 5.7 referred to those sub-watersheds with drainage arising primarily from the Town of Culpeper. This reference will not be included in the revised report.

23. **Page 60, Section 5.6, For each allocation scenario please document the total load for each source at existing levels and allocated levels.** Two table have been added for each of the five TMDL alternatives. The first table will describe loads applied to the land surface by source and sub-watershed, while the second table will describe loads delivered to the edge of stream and the outlet by source. These tables are number Table 5-7 through Table 5-16 and can be found on pages 64-68 in the revised report.

24. **Page 72, Table 6.1, The titles for each column are cut off. What are the cattle-in-stream reductions for Scenario N?** *[NOTE: Chapter 6 was revised during the EPA review process in April 2001. Therefore, this response no longer applies.]*

Table 6-1 has been replaced with the following table and figure to explain the Stage I recommendation, and the change from base future conditions:

Table 6-1. Future and Stage I Exceedance Rates

			Exceedance Rates	
	% Reductions		Daily	30-day Geometric Mean
Scenario	"cows-in-streams	urban washoff	1000 cfu/100 mL	190 cfu/100 mL
Future	0%	0%	13.5%	67.7%
Stage I	60%	50%	10.0%	34.5%

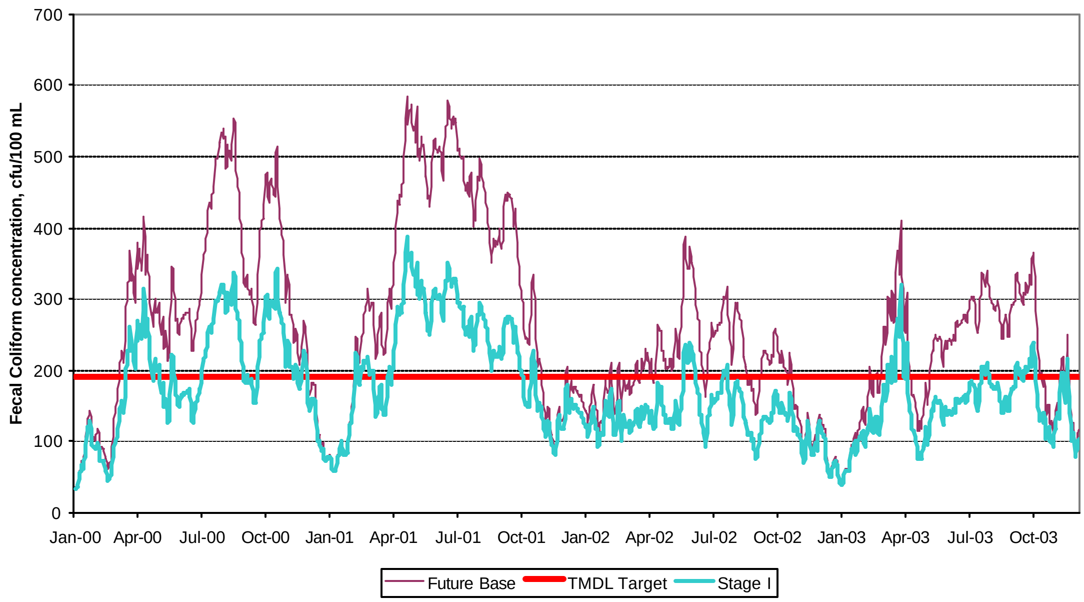

Figure 6-1. Stage I 30-dayGeometric Mean FC Concentrations

25. Additional information on the die-off rate used in this model is necessary.

A description of how die-off was handled in the model has been included in Section 4.7.5 (p. 51-52), and will read:

"Die-off in storage was incorporated in the Fortran program used to distribute livestock fecal coliform loading to pervious land segments. An in-storage die-off percentage of 97.73% was calculated from a series of measurements of fecal coliform in fresh manure and in stored manure during land application.

Die-off from the pervious portions of the watershed was modeled with HSPF's first-order decay function. For all general quality constituents, the REMQOP factor is approximately equal to the first order decay coefficient, k, in Chick's Law. Chick's Law is generally written as follows:

$$N_t = N_0 * e^{(-k*t)}$$

where N_t and N_o are the final and initial sample concentrations, respectively, and t is the time in between samples.

REMQOP was calculated as 0.11 from research by Thelin and Gifford (J. Environ. Qual. 12(1): 57-63). Since REMQOP = ACQOP/SQOLIM, SQOLIM can be expressed as a multiple of ACQOP (MF x ACQOP). For k=0.11, this equals a MF = 9, which was the value used in the Mountain Run model.

Impervious portions of the watershed also used the first order decay function. In research conducted by Olivieri et al, 1977, bacteria concentrations in runoff appeared to be independent of the days since the last rainfall event, indicating either a very rapid buildup or an accumulation limit (maximum loading) not much greater than daily loading. A lower multiplication factor was indicated by this reasoning, and a MF = 2 was arrived at through calibration.

In-stream die-off was also included in the model for which FSTDEC was set equal to 1.0. Table 4-15 includes a listing of the various input parameters used in HSPF simulations for Mountain Run."

References

Thelin, R. and G. F. Gifford. 1985. Fecal coliform release patterns from fecal material of cattle. *J. Environ. Qual.* 12(1): 57-63.

Olivieri, V. P., C. W. Kruse, K. Kawata, and J. E. Smith. 1977. Microorganisms in urban stormwater. EPA-600/2-77-087. U. S. Environmental Protection Agency. Cincinnati, Ohio.

Addenda

ADDENDUM A - Distribution of Loads by Land Use – Mountain Run Watershed

Average Annual FC Loads Applied to the Land By Land Use
Existing Conditions cfu * 10,000,000,000/yr

	Pervious							
WS	**Urb/Dev**	**RuralRes**	**Forest**	**Cropland**	**Pasture**	**LoafLot**	**Impervious**	**Total**
1	0	236	821	69	19,488	0	0	20,615
2	0	92	14,928	3,436	171,707	9,724	0	199,887
3	0	102	5,013	221	72,899	6,217	0	84,453
4	2,240	512	5,622	1,548	110,607	9,158	2,916	129,687
5	2,340	213	177	1,412	76,496	19,239	3,080	99,877
6	3,038	658	3,979	2,347	640,136	3,303	3,989	653,463
7	59	12	108	1,700	154,553	21,211	77	177,644
8	5,396	65	540	223	160	0	7,006	6,384
9	27,784	1	91	0	323	0	36,768	28,199
10	6,820	466	5,523	3,915	690,248	47,187	8,969	754,159
11	2,708	882	1,792	5,381	264,712	8,174	3,340	283,648
12	937	64	12,409	2,616	270,873	26,267	1,249	313,164
13	0	12	3,440	34	162	0	0	3,649
14	23,273	61	2,436	303	69,592	0	30,182	95,665
15	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0
Total	**74,593**	**3,376**	**56,878**	**23,206**	**2,541,958**	**150,481**	**97,577**	**2,948,070**

Future Conditions cfu * 10,000,000,000/yr

	Pervious							
WS	**Urb/Dev**	**RuralRes**	**Forest**	**Cropland**	**Pasture**	**LoafLot**	**Impervious**	**Total**
1	0	236	821	69	19,488	0	0	20,615
2	0	101	14,907	3,430	170,385	9,724	0	198,547
3	0	205	5,007	211	64,277	6,217	0	75,917
4	3,177	1,387	5,442	1,446	79,220	9,158	2,916	99,831
5	3,128	234	169	1,385	72,280	19,239	3,080	96,435
6	3,928	1,642	3,561	2,121	513,058	3,303	3,989	527,613
7	70	13	108	1,700	154,534	21,211	77	177,634
8	5,581	92	529	210	140	0	7,006	6,552
9	27,775	1	91	0	323	0	36,768	28,190
10	7,730	677	5,481	3,857	659,059	47,187	8,969	723,991
11	3,624	1,720	1,612	5,160	230,760	8,174	3,340	251,050
12	1,040	93	12,396	2,589	264,892	26,267	1,249	307,277
13	0	12	3,440	34	162	0	0	3,649
14	24,691	62	2,388	290	66,495	0	30,182	93,927
15	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0
Total	**80,743**	**6,474**	**55,954**	**22,501**	**2,295,074**	**150,481**	**97,577**	**2,708,804**

Existing Conditions: Annual Fecal Coliform Loads Delivered to the Edge-of-Stream

(cfu/yr x 10,000,000,000) (from Surface Runoff and Direct Nonpoint Sources)

Reach	Land Uses						Impervious	Direct NPS	
	Urban/Dev	RuralRes	Forest	Cropland	Pasture	LoafingLot	Washoff	Cows-in -stream	Straight Pipes
1	0	4	13	1	366	0	0	0	0
2	0	2	247	144	5,616	1,009	0	314	175
3	0	6	133	10	1,397	756	0	435	6
4	145	12	71	54	2,431	168	668	544	7
5	181	9	2	103	2,349	405	706	622	460
6	161	13	40	81	15,284	0	912	1,528	34
7	4	0	1	112	3,563	675	18	462	21
8	126	1	5	4	2	0	1,604	0	1
9	575	0	1	0	4	0	8,409	0	1
10	154	14	79	167	20,722	4,279	2,049	1,750	69
11	148	48	45	430	11,506	0	764	498	272
12	85	2	170	116	5,568	1,128	287	451	149
13	0	0	39	1	5	0	0	0	53
14	662	1	35	6	1,347	0	6,905	59	760
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
Total	2,241	114	880	1,228	70,162	8,421	22,323	6,663	2,009
% of Total	2.0%	0.1%	0.8%	1.1%	61.5%	7.4%	19.6%	5.8%	1.8%

Future Conditions: Annual Fecal Coliform Loads Delivered to the Edge-of-Stream

(cfu/yr x 10,000,000,000) (from Surface Runoff and Direct Nonpoint Sources)

Reach	Land Uses						Impervious	Direct NPS		Permitted
	Urban/Dev	RuralRes	Forest	Cropland	Pasture	LoafingLot	Washoff	Cows-in -stream	Straight Pipes	STPs
1	0	4	13	1	366	0	0	0	0	
2	0	2	247	144	5,582	1,009	0	312	175	
3	0	6	133	9	1,405	756	0	387	6	
4	207	12	74	53	2,417	168	949	395	7	[illegible]
5	242	9	2	104	2,346	405	943	587	460	
6	208	14	39	79	14,890	0	1,180	1,231	34	
7	5	0	1	112	3,563	675	21	462	21	
8	132	1	5	4	2	0	1,659	0	1	
9	580	0	1	0	4	0	8,413	0	1	
10	175	14	84	174	20,427	4,279	2,323	1,666	69	[illegible]
11	202	48	44	431	11,507	0	1,022	436	272	
12	94	2	169	115	5,563	1,128	319	442	149	
13	0	0	39	1	5	0	0	0	53	
14	703	1	36	6	1,328	0	7,324	57	760	8
15	0	0	0	0	0	0	0	0	0	
16	0	0	0	0	0	0	0	0	0	
Total	2,548	114	886	1,233	69,405	8,421	24,152	5,976	2,009	9
% of Total	2.2%	0.1%	0.8%	1.1%	60.0%	7.3%	20.9%	5.2%	1.7%	0.9

TMDL Alt 1: Annual Fecal Coliform Loads Delivered to the Edge-of-Stream

(cfu/yr x 10,000,000,000) (from Surface Runoff and Direct Nonpoint Sources)

Reach	Land Uses						Impervious Washoff	Direct NPS Cows-in -stream	Direct NPS Straight Pipes	Permitted STPs
	Urban/Dev	RuralRes	Forest	Cropland	Pasture	LoafingLot				
1	0	3	13	1	366	0	0	0	0	
2	0	2	246	144	5,582	1,009	0	0	0	
3	0	3	133	9	1,405	756	0	0	0	
4	207	4	73	51	2,417	168	417	0	0	[illegible]
5	242	2	2	103	2,342	404	415	0	0	
6	208	6	38	78	14,885	0	520	0	0	
7	5	0	1	111	3,562	675	9	0	0	
8	132	1	5	4	2	0	730	0	0	
9	580	0	1	0	4	0	3,707	0	0	
10	175	2	84	174	20,422	4,278	1,025	0	0	[illegible]
11	195	8	43	420	11,493	0	450	0	0	
12	94	2	169	115	5,563	1,128	140	0	0	
13	0	0	39	1	5	0	0	0	0	
14	697	1	35	6	1,327	0	3,227	0	0	8[illegible]
15	0	0	0	0	0	0	0	0	0	
16	0	0	0	0	0	0	0	0	0	
Total	2,534	34	883	1,218	69,374	8,419	10,640	0	0	9[illegible]
% of Total	2.7%	0.0%	0.9%	1.3%	73.7%	8.9%	11.3%	0.0%	0.0%	1.1[illegible]

TMDL Alt 2: Annual Fecal Coliform Loads Delivered to the Edge-of-Stream

(cfu/yr x 10,000,000,000) (from Surface Runoff and Direct Nonpoint Sources)

Reach	Land Uses						Impervious Washoff	Direct NPS Cows-in -stream	Direct NPS Straight Pipes	Permitted STPs
	Urban/Dev	RuralRes	Forest	Cropland	Pasture	LoafingLot				
1	0	3	13	1	366	0	0	0	0	
2	0	2	246	144	5,582	1,009	0	56	0	
3	0	3	133	9	1,405	756	0	70	0	
4	207	4	73	51	2,417	168	0	71	0	[illegible]
5	242	2	2	103	2,342	404	0	106	0	
6	208	6	38	78	14,885	0	0	223	0	
7	5	0	1	111	3,562	675	0	83	0	
8	132	1	5	4	2	0	0	0	0	
9	580	0	1	0	4	0	0	0	0	
10	175	2	84	174	20,422	4,278	0	283	0	[illegible]
11	195	8	43	420	11,493	0	0	79	0	
12	94	2	169	115	5,563	1,128	0	79	0	
13	0	0	39	1	5	0	0	0	0	
14	697	1	35	6	1,327	0	0	10	0	8[illegible]
15	0	0	0	0	0	0	0	0	0	
16	0	0	0	0	0	0	0	0	0	
Total	2,534	34	883	1,218	69,374	8,419	0	1,060	0	9[illegible]
% of Total	3.0%	0.0%	1.0%	1.4%	82.1%	10.0%	0.0%	1.3%	0.0%	1.2[illegible]

TMDL Alt 3: Annual Fecal Coliform Loads Delivered to the Edge-of-Stream

(cfu/yr x 10,000,000,000) (from Surface Runoff and Direct Nonpoint Sources)

	Land Uses							Direct NPS		
Reach							Impervious	Cows-in	Straight	Permitted
	Urban/Dev	RuralRes	Forest	Cropland	Pasture	LoafingLot	Washoff	-stream	Pipes	STPs
1	0	3	13	1	366	0	0	0	0	
2	0	2	246	144	5,582	1,009	0	25	0	
3	0	3	133	9	1,405	756	0	31	0	
4	207	4	73	51	2,417	168	255	27	0	[illegible]
5	242	2	2	103	2,342	404	254	41	0	
6	208	6	38	78	14,885	0	318	86	0	
7	5	0	1	111	3,562	675	6	37	0	
8	132	1	5	4	2	0	403	0	0	
9	580	0	1	0	4	0	2,046	0	0	
10	175	2	84	174	20,422	4,278	565	115	0	[illegible]
11	195	8	43	420	11,493	0	276	35	0	
12	94	2	169	115	5,563	1,128	86	35	0	
13	0	0	39	1	5	0	0	0	0	
14	697	1	35	6	1,327	0	1,781	0	0	8
15	0	0	0	0	0	0	0	0	0	
16	0	0	0	0	0	0	0	0	0	
Total	2,534	34	883	1,218	69,374	8,419	5,990	433	0	9
% of Total	2.8%	0.0%	1.0%	1.4%	77.2%	9.4%	6.7%	0.5%	0.0%	1.1

TMDL Alt 4: Annual Fecal Coliform Loads Delivered to the Edge-of-Stream

(cfu/yr x 10,000,000,000) (from Surface Runoff and Direct Nonpoint Sources)

	Land Uses							Direct NPS		
Reach							Impervious	Cows-in	Straight	Permitted
	Urban/Dev	RuralRes	Forest	Cropland	Pasture	LoafingLot	Washoff	-stream	Pipes	STPs
1	0	3	13	1	366	0	0	0	0	
2	0	2	246	144	5,582	1,009	0	16	0	
3	0	3	133	9	1,405	756	0	39	0	
4	207	4	73	51	2,417	168	175	39	0	[illegible]
5	242	2	2	103	2,342	404	943	30	0	
6	208	6	38	78	14,885	0	1,180	61	0	
7	5	0	1	111	3,562	675	21	23	0	
8	132	1	5	4	2	0	306	0	0	
9	580	0	1	0	4	0	1,284	0	0	
10	175	2	84	174	20,422	4,278	430	84	0	[illegible]
11	195	8	43	420	11,493	0	189	22	0	
12	94	2	169	115	5,563	1,128	59	23	0	
13	0	0	39	1	5	0	0	0	0	
14	697	1	35	6	1,327	0	1,352	6	0	8
15	0	0	0	0	0	0	0	0	0	
16	0	0	0	0	0	0	0	0	0	
Total	2,534	34	883	1,218	69,374	8,419	5,938	342	0	9
% of Total	2.8%	0.0%	1.0%	1.4%	77.3%	9.4%	6.6%	0.4%	0.0%	1.1

TMDL Alt 5: Annual Fecal Coliform Loads Delivered to the Edge-of-Stream

(cfu/yr x 10,000,000,000) (from Surface Runoff and Direct Nonpoint Sources)

Reach	Land Uses						Impervious	Direct NPS		Permitted
	Urban/Dev	RuralRes	Forest	Cropland	Pasture	LoafingLot	Washoff	Cows-in -stream	Straight Pipes	STPs
1	0	3	13	1	366	0	0	0	0	
2	0	2	246	144	5,582	1,009	0	16	0	
3	0	3	133	9	1,405	756	0	19	0	
4	207	4	73	51	2,417	168	302	20	0	8
5	242	2	2	103	2,342	404	301	30	0	
6	208	6	38	78	14,885	0	377	61	0	
7	5	0	1	111	3,562	675	21	23	0	
8	132	1	5	4	2	0	529	0	0	
9	580	0	1	0	4	0	2,685	0	0	
10	175	2	84	174	20,422	4,278	1,466	84	0	8
11	195	8	43	420	11,493	0	326	22	0	
12	94	2	169	115	5,563	1,128	319	23	0	
13	0	0	39	1	5	0	0	0	0	
14	697	1	35	6	1,327	0	2,337	3	0	8
15	0	0	0	0	0	0	0	0	0	
16	0	0	0	0	0	0	0	0	0	
Total	2,534	34	883	1,218	69,374	8,419	8,663	300	0	9
% of Total	2.7%	0.0%	1.0%	1.3%	75.1%	9.1%	9.4%	0.3%	0.0%	1.1

ADDENDUM B – Corrected Table 5.5

There is a data entry error in table 5.5, reach 9. In the urban wash-off column, the correct entry should read 8,413 instead of 0. The corrected version of Table 5.5 is reproduced below.

Table 5-5. Future Conditions: Annual FC Loads Delivered to the Edge-of-Stream
cfu * 10,000,000,000/yr

Reach	Livestock	Wildlife	Septic	Urban Pervious	Straight Pipes	Cows-in -streams	Urban Washoff	Permitted	Total
1	366	19	2	0	0	0	0	0	386
2	6,544	338	1	0	175	312	0	0	7,370
3	1,402	148	3	0	6	387	0	0	1,947
4	2,406	122	10	203	7	395	949	83	4,176
5	2,737	33	13	240	460	587	943	0	5,013
6	14,890	133	14	206	34	1,231	1,180	1	17,690
7	4,228	23	2	5	21	462	21	0	4,762
8	0	15	0	129	1	0	1,659	0	1,804
9	0	9	0	574	1	0	8,413	0	8,998
10	24,702	180	18	173	69	1,666	2,323	83	29,214
11	11,523	198	75	191	272	436	1,022	0	13,718
12	6,656	219	1	94	149	442	319	0	7,880
13	0	45	0	0	53	0	0	0	98
14	1,314	66	7	688	760	57	7,324	829	11,046
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
Total In	**76,769**	**1,548**	**147**	**2,504**	**2,009**	**5,976**	**24,153**	**995**	**114,101**
Total Out	**54,539**	**1,202**	**106**	**1,664**	**1,051**	**2,718**	**12,758**	**438**	**74,476**